CYTO-EMBRYOLOGY OF SOME LABIATAE

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"He it is WHO sendth down water from the sky, and therewith we bring forth vegetation of every kind; We bring forth the green buds from which are derived thick-clustered grains,... observe upon the fruit thereof when they (plants) bear fruits, and upon its ripening. Lo! here in verily are protents for people who believe."

AL-QUR'AN
(Al-An'am : 12:100)

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CERTIFICATE

This is to certify that the work presented in this dissertation entitled 'Cytoembryology of some Labiatae' is the original piece of research work carried out by Miss Fauzia Siddiqi under my supervision and guidance and has not been submitted elsewhere for the award of any other degree or diploma.

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Fauzia Siddiqi

(FAUZIA SIDDIQI)

PREFACE

Consideratble literature has accumulated on the cyto-embryology of Labiatae during the last four decades. Therefore, a humble attempt has been made in the following pages to review the available literature on the cyto-embryology of Labiatae.

CONTENTS

INTRODUCTION

The development of thought on the classification of Labiatae is traced from the classical times to the present day with particular reference to the boundaries of the family, its relationship to other families such as Orobanchaceae and Verbenaceae, and the general arrangement of the tribes and genera. However, divergent views have been put forward regarding the exact relationships of the family Labiatae. Linnaeus (1707-1778) provided a sexual system having 24-classes for all plants. The plants were sorted out on the basis of the number and nature of the stamens. There are generally 4 stamens in Labiatae (two short and two long) and he placed the family in class-14, the didynamia. Labiatae together with four others was placed in the 10th order of the gamopetalae, bicarpellatae, the Lamiales by Bentham and Hooker (1862-1883), Bessey (1893), Gunderson (1950), Benson (1957) and Cornquist (1968). Bessey (1893) separated Labiatae and Verbanaceae in order Lamiales on the basis of corolla and gynoecium. Hutchinson (1959) first did likewise but later restricted Lamiales to Labiatae and segregated the Verbenaceae to Verbenales and considered the two as absolutely unrelated, placed the former in his Herbaceae and the later in his Lignosae.

Engler and Prantl (1895) included Labiatae together with 19 others in the 6th order of Dicotyledonae, Sympetalae, the Tubiflorae. Hallier (1868-1932), Wettstein (1935), Rendle (1952) and Corner (1976) followed the Engler and Prantl system and considered that the family belongs to Tubiflorae. Wettstein (1862) and Corner (1976) have indicated a belief that Tubiflorae is an unnatural assemblage of families.

The family Labiatae is a fairly large family having 200 genera and 3,000 species (Mukerjee, 1984). Earlier Willis (1966) had reported 180 genera and 3,500 species. It is almost cosmopolitan being distributed both in temperate and tropical regions. It is very well represented in the Mediterranean region where the plants form the dominant part of the vegetation. About 250 species are found in India in the Himalayas and the hills of Assam and Peninsular India. Quite a good number are also common in plains, e.g., Ocimum sanctum, Salvia plebeja, Leonurus, Anisomeles indica, Leucas etc. Many species of Nepata, Salvia, Mentha and Thymus, and a few species of Pholmis, Stachys, Scutellaria, Dracocephalum etc. are Himalayan plants.

Leucas aspera, Lavandula burmanni, Acrocephalus capitus, Ocimum basilicum, O. sanctum etc.are herbs. Salvia aegyptiaca is profusely branched undershrub. Ocimum gratissimum (Shrubby basil) is a profusely branched shrub. Species of Leucosceptrum (India) and Hyptis (Brazil) are trees. Species of Mentha are

marsh plants. Some species of Scutellaria (America) and species of Stenogyne are climbing plants, although climbing habit is extremely rare in this family. Some plants are extremely xerophytes such as species of Rosmarinus, a shrubby plant with thick cuticle, leaves rolled back and stomata situated in hairy grooves on the lower side of the leaf. Some plants possess suckers, e.g., Mentha arvensis (Mathur, 1956).

Economically the family is important as a source of volatile aromatic essential oils, food and garden ornamentals. Among the more important essential oil yielding plants are Salvia, Lavandula, Rosamarinus, Mentha and Pogostemon. Important culinary herbs prized for the flavour or aroma imparted to food are Origanum, Hyssopus, Ocimum, Thymus and Satureja. Marrubium is used in the preparations of medicines and confections. The principal ornamentals include Salvia, Ajuga, Leonotis, Physostegia, Monarda, Nepata, Stachys, Thymus, Coleus, Lavandula and Pycnanthemum (Lawrence, 1951). Food products are obtained from Stachys species.

The genus Ocimum comprises about 150 species (Willis, 1966) which have attracted the botanists for a long time due to their medicinal value. Ocimum is a genus of aromatic herbs, under-shrubs or shrubs distributed in tropical and warm temperate regions of the world. Nine species are exotic. Several species of Ocimum yield essential oils which are valued in medicine and perfumery. A few are rich sources of camphor. O. sanctum, commonly called as Holy basil or Krishna Tulsi,

is largely cultivated by Hindus in the gardens, homes and near temples being regarded as one of the most sacred plants.

A considerable amount of embryological work has been done on this family by Schacht (1850), Hofmeister (1858a, b), Chatin (1874), Warming (1873, 1878), Vesque (1878, 1879), Elfving (1879), Jonsson (1879-1880, 1881), Guignard (1882b, 1893), Soltwedel (1882), Hubert (1896), Rupert (1902), Billings (1909), Sharp (1911), Schnarf (1917b, 1931), Guerin (1979), Soueges (1921b, c), Schurhoff (1927), Gorczynski (1929), Lietz (1929), Wolf (1929), Laws (1930), Ruttle (1931, 1932), Junell (1934, 1937), Bushnell (1936), Carlson and Stuart (1936), Finn (1939), Murthy (1940, 1941, 1942, 1947), Lietner (1942), Crete (1942, 1943, 1951d, 1963), Ganguly (1948), Admiral'skaya (1960), Jaitly (1966, 1968, 1969, 1972), Kandelaki and Kobakhidzi (1977), and Satyanarayana (1985). Due to economic, medicinal and ornamental importance of Labiatae, knowledge of their morphology and anatomy is most desirable. Moreover, the detailed embryological studies like male and female gametophytes, type of endosperm and embryonal development, formation of seed and fruit may give it a more exact and suitable taxonomic position as well as affinities with other related families. Cyto-embryological studies are also helpful in tracing the cause of incompatibility, lowered pollen fertility and seed setting, abortive or defective embryos and seeds and lower seed germination and overcoming

practical problems. Keeping these points in view detailed morphological and cyto-embryological studies of some Labiatae have been planned to be carried out.

HISTORICAL

The floral organogeny takes place in acropetal succession in Salvia (Saunders, 1940), Ocimum adscendens (Murthy, 1946), and Lavandula vera (Rabotyagov, 1980), while in Anisomeles (Murthy, 1946; Ganguly, 1948) and Leonurus (Ganguly, 1948) it is alternately acropetal and basipetal successions.

The earliest contribution on the embryology in Labiatae is the work of Chatin (1874), who studied the development of pollen grains and ovule. Microsporangium is tetrasporangiate and the development of the anther wall layers conforms to the Dicotylendonous type of Davis (1966). The anther wall comprises an epidermis, fibrous endothecium, middle layers and a glandular tapetum. The middle layers are 2-3 and degenerate during pollen maturity. The glandular tapetum is of dual origin and multinucleate (Davis, 1966). Micro-archesporium is uniseriate. Simultaneous cytokinesis in the microspore mother cells follows meiosis. The microspore tetrads are tetrahedral, isobilateral or decussate. Several unusual features are associated with the process of micro-sporogenesis in Salvia mellifera and S. apiana (Carlson and Stuart, 1936). The nucleolar budding occurs in S. apiana during meiosis. Cytomixis is an abnormality appearing in diakinesis of S. apiana. Anaphase may be accompanied by

non-disjunction of some bivalents in S. mellifera and S.apiana (Carlson and Stuart, 1936).

Each microspore is monoploid (N). The pollen grains may be prolate or sub-oblate. The exine and endine vary from genus to genus and sometimes within the species (Nair, 1965). On the basis of the apertures the pollen grains are classified into 3-zonicolpate and stephanocolpate (Rao and Shukla, 1975). The 3-zonicolpate pollen grains are shed at 2-nuclete stage and 6-colpate at 3-nucleate stage (Rao and Shukla, 1965).

The ovule in Labiatae is hemiantropous to anatropous, unitegmic and tenuinucellar (Davis, 1966). The ovule of Labiatae has a single massive integument and single layered nucellar epidermis. The female archesporium is generally single-celled in Labiatae. However, 2-celled female archesporium has been reported in Galaeopsis pubescens (Strasburger, 1879, 1889), Lamium (Schnarf, 1917), Pogostemon patchouli (Junell, 1937) and Leonurus (Ganguly, 1948). Multiple archesporium has been observed in Leonurus (Ganguly, 1948). Junell (1937) has reported the presence of the potential archesporial cells in Molucella and Pogostemon around the base of the developing megaspore mother cells.

Jonsson (1881) studied the development of the female gametophyte and reported that the megaspore mother cell undergoes meiosis and forms a linear tetrad of megaspores.

The female gametophyte in Labiatae conforms to the Polygonum type. The synergids are hooked or beaked in Labiatae. The polar nuclei fuse before or at the time of fertilization. The antipodals are ephemeral and degenerate after fertilization. except in Physostegia (Sharp, 1911).

However, several interesting cases of double and multiple embryo sacs have been observed in Leonurus (Ganguly, 1948). Twin embryosacs have been reported in Leonurus (Ganguly, 1948) and Salvia officinalis (Polishchuk, 1972), where both the embryo sacs are almost of equal size, one of them above the other. Both the embryo sacs are 4-nucleate. In other instance in Leonurus (Ganguly, 1948), the smaller embryo sac lies at the micropylar part at the side of the larger sac and contains five nuclei — one pair at each of the two poles and one nucleus at the centre. The lower portion of this smaller embryo-sac is deflected on the larger one.

In a multiple embryo-sac in Leonurus (Ganguly, 1948), there are three embryo-sacs in the upper broadened part and two in the lower. Of the three in the upper, one is eight-nucleate gametophyte with four nuclei at the two poles, and the other two are four-nucleate, each having two nuclei at the two ends; of the two nuclei at the lower end in each of the said 4-nucleate embryo-sacs, one has developed a cytoplasmic membrane forming an antipodal like cell and the other remains free. The two embryo-sacs in the chalazal portion are typically four nucleate.

The pollination in Labiatae is entomophilous and anemophilous. The fertilization is porogamous. The development of endosperm in Labiatae conforms to Cellular type. The primary endosperm cell divides transversely and according to the planes of division in the two chambers, Schnarf (1917b) recognized four main endosperm types -- Scutellaria, Brunella, Stachys and Galaeopsis. Formation of endosperm haustoria is of common occurrence in Labiatae.

The embryogeny in Labiatae generally conforms to the Onagrad type (Davis, 1966). The mode of development of the embryo in Ajuga reptans, Teucrium botrys, Amethystea coerula, Prasium majus, Scutellaria minor, Marrubium pannonicum, Sideritis hirsuta, S. scordiodes, Nepata cataria, N. macrantha, Dracocephalum ruyschiana, D. mairci, D. thymifolium, Lophanthus chinensis, Lallemantia peltata, L. iberica, Brunella vulgaris, Melittis melissophyllum, Pholmis apiana, Leonurus cardiaca, Salvia sclares, Thymus serphyllum, Origanum vulgare, Perilla arguta, Ocimum basilicum (Johansen, 1950), Salvia columnae (Jaitly, 1968), Mentha aquatica (Jaitly, 1969), S. coccinea and S. splendens conforms to Mentha variation of Onagrad type. However, the embryogeny in Galaeopsis tetrahit, G. pyrenaica, Bollota foetida, Lamium purpureum and Urtica pulutifera (Johansen, 1950) conforms to Lamium variation of Asterad type.

The fruit in Labiatae is usually a group of four achenes or nutlets which are equally developed, each containing a

single seed in Salvia, Orthosiphon, Acrocephalus and Lavandula. In Gomphostemma the fruit is drupaceous. In Ocimum sanctum the fruit is reported to be schizocarpic and carcerulus (Mathur, 1956).

The seeds of Labiatae may be albuminous or ex-albuminous. The albuminous seeds are reported in Leucas and Pogostemon (Jaitly, 1969), while in Hyptis, Mentha, Ocimum and Salvia (Jaitly, 1969) the seeds are ex-albuminous.

FLORAL ORGANOGENY

The floral organogeny takes place in acropetal succession in the described Labiatae, viz., Ocimum basilicum, O. canum, O. sanctum (Murthy, 1940), Salvia (Saunders, 1940), O. adscendens (Murthy, 1946), while in Anisomeles (Murthy, 1946 and Ganguly, 1948) and Leonurus (Ganguly, 1948) it is alternately acropetal and basipetal successions.

The primodium of the flower first makes its appearance as a knob-like protuberance in the axil of the bract in Ocimum adscendens (Murthy, 1946). The calyx is the first to be differentiated from the meristematic cells of the axis (Fig.13). Then the receptacle broadens. The primodium of the corolla is differentiated next, and because of the epipetalous character of the family the stamens arise as branches from the corolla. The development of the stamens is completed before the ovary has made little progress in its differentiation, so that the flower becomes protandrous (Figs. 14 and 15). The primodium left after the differentiation of calyx, corolla and stamens is utilized in the formation of gynoecium. The carpels arise from the dome-shaped apex and their two lobes grow towards each other. They form an arch over the central region and grow upwards for some distance. They do not fuse for a considerable

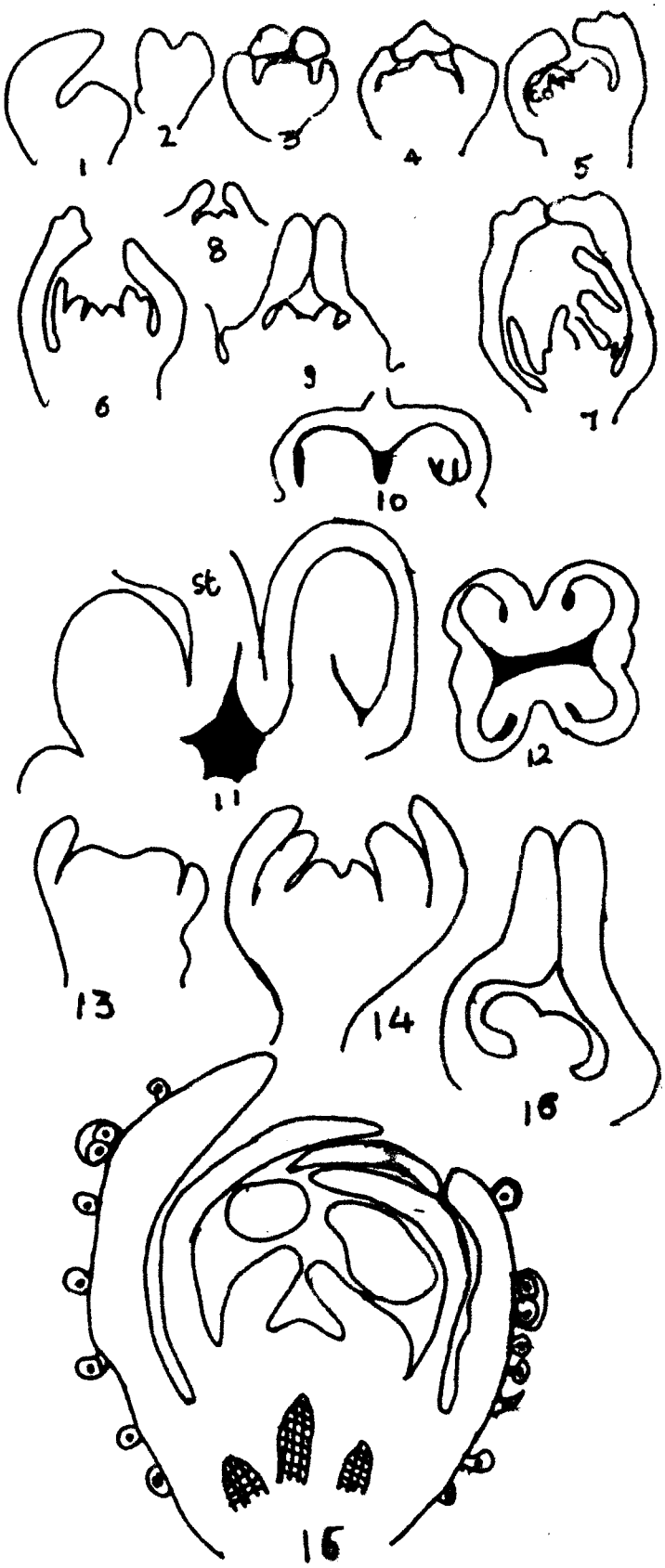
period during their elongation. Finally the two carpels fuse in the central stylar region while their tips remain free, forming the stigmatic lobes (Figs. 14, 15 and 16). The ovules arise as protuberances from the base of the ovarian chamber and the ovary wall adjusts itself according to their growth so that four distant ovary lobes are formed and the style becomes gynobasic. The nectiferous disc is differentiated next from the massive receptacle and its four lobes alternate with the ovary lobes ultimately. During the growth of the ovules the funiculus of each ovule enlarges into an obturator, as in Ocimum canum, O. sanctum and O. basilicum (Murthy, 1940, 1946). The differentiation of the floral parts occur in the following order; viz., calyx, corolla, stamens, ovary and disc.

In Anisomeles and Leonurus (Ganguly, 1948), the primodium of the flower is at first visible in the axil of the bracteole as a dome shaped protuberance (Fig. 1). The sepals are the first members to appear as prominences from the margin of the receptacle (Fig. 2). As the calyx grows the central mass of cells (the primodium) again becomes broad and completely covered by the sepals (Fig. 3). The staminal primodia then arise from the base of the sepals which are pushed out (Fig. 4). Soon after this the primodia of the petals emerge from the dorsal surface of the stamens (Fig. 5). As the carpel primodium differentiates the calyx shows pronounced growth and then the margins are incurved. The central

primodium still remains undifferentiated. As the sepals overtop the anther primodia, the ovary primodium becomes wavy.

The initiation of ovary wall occurs at the base of the stamens, after the latter have been overgrown by the petals. The petals and stamens have a common origin, one appearing a little later than the other (Fig. 7). In longitudinal section they appear as two protuberances and a depressed area at the centre (Fig. 6). By further growth of the wall and a simultaneous broadening of the central portion, the cavity of the ovary is formed. When the wall meets at the tip the ovules are seen to arise on the broadened central portion at the base of the ovarian wall (Fig. 8). A transverse section of the ovary shows that the ovules arise on the placenta formed at the margin of the two united carpels (Fig. 12). The placenta cushion thus takes its origin as an united structure, the two ovules growing on the two sides of it in diametrically opposite directions. The ovarian wall, joins at the centre producing ovarian cavity. The united carpels continue their growth upwards to form the style and stigma (Fig. 9). The style is gynobasic (Figs. 10 and 11).

Rabotyagov (1980) discussed few structural deviations in Lavandula vera such as doubleness, fascination, prolification abnormality and multilobate form of ovaries and appearance of a number of naked ovules in the receptacle.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MICROSPORANGIUM

The microsporangium is tetrasporangiate in the described labiatae.

The literature about the development of the anther wall layers is rather meagre.

The young anther is composed of homogenous meristematic cells surrounded by the epidermis. It soon becomes four lobed and a row of hypodermal cells differentiates as the male archesporium in each lobe. The archesporial cells are densely cytoplasmic and possess conspicuous nuclei. The formation of anther wall layers takes place by periclinal divisions in the archesporial cells to form the primary parietal layer and an inner primary sporogenous layer. The primary parietal layer divides periclinally to form outer and inner secondary parietal layers. The outer secondary parietal layer divides periclinally and forms two layers — the outer one differentiates as endothecium and the inner one as middle layer. The middle layer may again divide to form 2-3 layers. The inner secondary parietal layer functions directly as tapetum. Thus the anther wall layers comprises an epidermis, endothecium, middle layers and tapetum, and the development of the anther wall layers in the described Labiatae, viz., Lamium amplexicaule

(Gorczyński, 1929), Salvia mellifera, S. apiana, S. columbariae, S. splendens, S. leucantha (Carlson and Stuart, 1936) and Leucas procumbens (Satyanarayana, 1985) conforms to Dicotyledonous type of Davis (1966).

The cells of the primary sporogenous layer divide mitotically and form a large number of microspore mother cells.

The epidermis is single layered having a protective function. The cells of the single layered endothecium increase in size and the cytoplasm becomes vacuolated. The cells of the endothecium elongate radially and develop fibrous bands which arise from the inner tangential walls, rarely from the radial walls. The fibrous thickenings generally develop in the cells of endothecium of Labiatae except the cleistogamous flowers of Lamium amplexicaule (Gorczynski, 1929). The fibrous thickenings are hygroscopic in nature and help in the dehiscence of the anther. Only those cells which possess some special means of mechanical thickening persist till the anther dehiscence. The anther dehisces by the longitudinal slits.

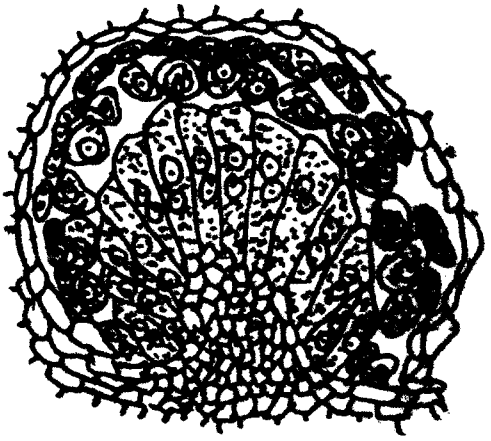
Next to the endothecium are 2-3 middle layers, which are generally ephemeral (Davis, 1966). Satayanarayana (1985) reported single middle layer in Leucas procumbens. The middle layer is sandwitched between the endothecium and the tapetum. The cells of the middle layer lack the ability to divide anticlinally. So that the middle layer fails to

cope with the multiplying and expanding sporogenous cells and concurrently it is crushed and absorbed during poâlen maturity. The formation of the middle layer is regarded as a relic feature.

The innermost layer of the anther wall is tapetum. It is of dual origin, one which develops from the parietal tissue and the other towards the connective. The inner tapetal cells are found to be elongated radially, while the outer ones are elongated tangentially. The tapetal cells attain the maximum development at the microspore tetrad stage and become multi-nucleate (fig. 17). Tapetum is glandular in Labiatae (See Davis, 1966). Endomitosis is of common occurrence and the tapetal cells become multinucleate (See Davis, 1966). Endomitosis is a type of mitosis in which chromosome duplication and chromatid separation takes places within the intact nuclear membrane and without the formation of a spindle.

Explanation of Figures

Fig. 17 - *Salvia mellifera*; Cross section of anther showing inner elongated tapetal cells and single layer of microspore mother cells (After Carlson and Stuart, 1936).



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MICROSPOROGENESIS

The primary sporogenous layer becomes multilayered due to repeated mitotic divisions in archesporial cells which function as microspore mother cells. The microspore mother cells undergo meiosis and produce microspore tetrads. The divisions in all the mother cells of an anther may not be synchronous. Thus the different stages of microsporogenesis may be present in the four chambers of the same anther. Cytokinesis is of simultaneous type. The microspore tetrads formed are tetrahedral, decussate and isobilateral depending on the direction of the spindles at metaphase II. The microspore tetrads are generally tetrahedral (Fig. 25) as reported in Salvia mellifera, S. apiana, S. splendens, S. gregii and S. leucantha (Carlson and Stuart, 1936). Sometimes decussate tetrads (Fig.24) are also reported in S. apiana and S. mellifera (Carlson and Stuart, 1936). Besides tetrahedral tetrads, isobilateral tetrads are also observed occasionally in Leucas procumbens (Satyanarayana, 1985).

Several unusual features are associated with the process of microsporogenesis in Salvia apiana and S. mellifera (Carlson and Stuart, 1936), which may be described as follows: The nucleolar budding occurs in S.apiana (Carlson and Stuart, 1936) during meiosis (Fig. 23). Beginning with the early prophase, the nucleolus in the microspore mother cell begins a process of budding, the first bud to be formed

reaching a size nearly the size of the main portion of the nucleolus, from which it finally becomes detached. Additional buds originate but they do not reach the size of the first bud and get separated from the main mass by constriction (Fig. 22). In the mean time synapsis occurs, when the buds formed are found on the side of the nucleolus facing the chromatin threads (Fig. 23). The budding process continues in diakinesis, when the bivalents, nucleolus and buds may be seen enclosed within a broken nuclear wall (Fig. 27). Cytomixis is an abnormality appearing in diakinesis of S. apiana (Carlson and Stuart, 1936). A conspicuous feature is the behaviour of nucleolus which extends as a slender process from the nucleus of one cell to the cytoplasm of an adjacent cell (Figs. 28, 29,32 and 33). The process occupies the centre of a bridge that is formed by the nuclear wall. Metaphase-I is normal in both S. apiana and S. mellifera (Carlson and Stuart, 1936) (Figs. 21 and 30), but anaphase-I may be accompanied by non-disjunction of some of the bivalents in S. mellifera (Fig. 18). In S. apiana (Carlson and Stuart, 1936) non-disjunction may occur (but is a comparatively rare abnormality), with bivalents more or less scattered over the spindles (Fig. 31). Prophase II is attended by nuclear elongation and conspicuous spindle fibres along which the chromosomes appear in approximately single file (Figs. 19 and 20). True furrowing occurs in both the species of Salvia. In S. mellifera the furrows extend centrifugally

without accompanying central vacuolation, while in S. apiana a central vacuole assists invagination (Carlson and Stuart, 1936). Irregularities in meiosis such as chromosome lagging and chromation extrusion are apparently not so uncommon in S. mellifera (Carlson and Stuart, 1936). The irregularities in meiosis suggest that hybridization has occurred at sometime in the history of the species.

Abnormalities such as cytomixis during diplotene and diakinesis, scattered chromosomes at metaphase I and non-uniform disjunction at anaphase I, abnormal arrangement of tetrad nuclei and reduced size of microspores are reported in wild Origanum vulgare L. by Vereshchagina and Malanina (1974).

Each cell of the tetrad differentiates as microspore having the monoploid (N) nucleus. The young microspores develop their own wall although they continue to lie for sometime within their original wall. The basic chromosome number in the family Labiatae is found to be 8 (Wanscher, 1934). The chromosome counts of various Salvia species reported by Carlson and Stuart (1936) are as follows:

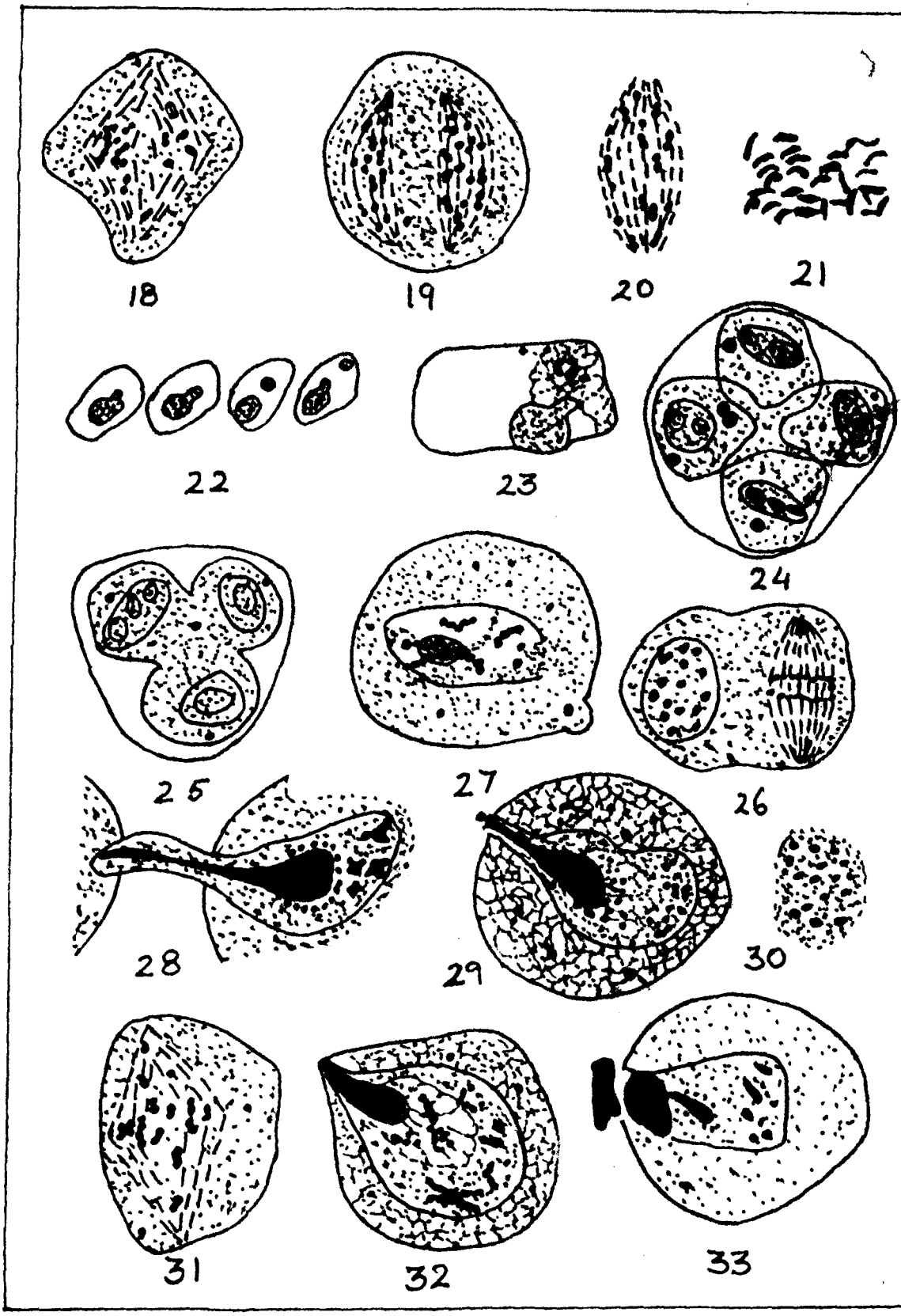
S.No.	Name of the plant	Number of Chromosomes(n)	2n
1	Salvia nipponica	8	-
2	S. columbarie	16	32
3	S. splendens	16	-
4	S. leucantha	16	-
5	S. apiana	15	30
6	S. mellifera	15	30

Bir and Sagoo (1982) also reported the chromosome numbers of few species of Labiatae from the central India, which are recorded in the following table:

S.No.	Name of the Plant	Number of Chromosomes
1	Salvia coccinea	n = 11
2	Leucas mollisima	n = 14
3	Plectranthus mollis	n = 14
4	Hyptis sauveolens	n = 14
5	Pogostemon purpurescens	n = 16
6	Coleus barbatus	n = 17
7	Ocimum sanctum	n = 18
8	Lavandula bipinnata	n = 20
9	Micromeria capetellata	n = 25
10	Ocimum canum	n = 40

Explanation of Figures

Figures 18-33. Salvia mellifera and S. apiana; Fig. 18. S. mellifera; Irregular anaphase I showing a bivalent nearly reaching a pole, while another undergoing disjunction with a diminutive spindle. Fig. 19. S. mellifera; Prophase II showing chromosomes tending to follow certain spindle fibres. Fig. 20. S. mellifera; View of a spindle in prophase II taken at right angles to the section shown in Fig.18. Fig. 21.S. mellifera; Somatic metaphase showing 30 chromosomes. Fig. 22. S. apiana; Formation and abstriction of nucleolar buds. Fig. 23. S. apiana; Synapsis, in which nucleolar buds are abstricted into the nuclear knot. Fig. 24. S. mellifera; Late stage of furrowing with decussate arrangement of micropores. Fig. 25. S. mellifera; Furrowing, with tetrahedral arrangement of microspores. Fig. 26. S. mellifera; Metaphase II. Fig. 27. S. apiana; Diakinesis, in which either extruded chromatin, or nucleolar buds,or both are found in the cytoplasm. The nuclear wall is broken, and what appears to be a bud is in the process of being eliminated from the cell. Fig. 28. S. apiana; Cytomixis. Fig. 29. S. apiana. Cytomixis. Abstriction of extracellular portion of the nucleolus. Fig. 30. S. apiana; Metaphase I. 15 chromosomes. Fig. 31. S. apiana; Irregular anaphase-I. A few bivalents are seen in each nucleus. Fig. 32. S. apiana; Cytomixis. Cell wall closing the opening through which nucleolus protuded. Fig. 33. S. apiana; Cytomixis (After Carlson and Stuart, 1936).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MALE GAMETOPHYTE

The male gametophyte of Labiatae has been studied in Mentha piperata (Wolf, 1929), Lamium amplexicaule (Gorczyński, 1929), Mentha (Ruttle, 1931), Salvia mellifera, S. apiana, S. Leucantha, S. splendens, S. columbarie (Carlson and Stuart, 1936), Phlomis tuberosa (Finn, 1939), Lamium album, Marrubium vulgare, Colebrookia oppositifolia, Mentha, Nepata, Salvia, Stachys, Origanum vulgare, Phlomis, Scutellaria repens (Nair, 1965), Ajuga, Anisomeles, Leucas aspera, Ocimum basilicum, Anisochilus carnosus (Rao and Shukla, 1975) and Leucas procumbens (Satyanarayana, 1985).

The microspore represents the beginning of the male gametophyte. The microspores in tetrads are at first surrounded by the original wall of the microspore mother cells which breaks down and the young microspores are liberated into anther loculus. The microspores are somewhat triangular in shape possessing dense cytoplasm and a thin wall.

Later, the microspore increases in size, becomes spherical, develops the exine and intine and its cytoplasm becomes vacuolated. As the division in the pollen grain starts, the vacuole disappears. The nucleus of the microspore divides mitotically forming a large vegetative and

a small generative cell and the pollen grains become 2-celled. The generative cell is demarcated by a hyaline cytoplasmic streak. The generative cell is detached, rounds up and comes to lie within the general cytoplasm and the pollen grain appears to be 2-nucleate. The division of the generative cell gives rise to two male gametes. Thus the pollen grain becomes 3-nucleate.

The pollen grains are shed at 2-celled stage in Salvia apiana (Carlson and Stuart, 1936), Colebrookia oppositifolia (Nair, 1965), Ajuga bracteosa, Anisomeles ovata, Leucas aspera (Rao and Shukla, 1975) and Leucas procumbens (Satyanarayana, 1985). On the other hand, the pollen grains are shed at 3-celled stage in Elsholtzia quadrifarium (Nair, 1965), Aniscchilus carnossus, Ocimum basilicum (Rao and Shukla, 1975). According to Nair (1965) in Labiatae, 3-colpate pollen grains are shed at 2-nucleate stage and 6-colpate at 3-nucleate stage.

The development of the male gametophyte in Labiatae has been studied by Finn (1939). According to him the division of the generative cell varies depending on whether it takes place in the pollen grain or in the pollen tube. In Phlomis tuberosa (Finn, 1939), the mechanism of division occurs in the pollen tube and the spindle fibres are absent.

The wall of the mature pollen grain is stratified.

It comprises two principal layers -- the intine and the exine. The exine of the pollen grains in Labiatae may be psilate, reticulate, thinner towards colpi margins, granulose, crustate, areolate or retipilate. The shape of the pollen grains may be prolate, sub-prolate or sub-oblate. The size of the pollen grains varies a lot within the family. The distinguishing characters of the pollen grains of Labiatae pointed out by Nair (1965) are presented in the tabular form.

S.No.	Plant	Shape of pollen grains	Size	Exine
1	Colebrookia oppositifolia Sm.	3-zonocolpate sub-prolate	21 x 17 µ	1 µ thick, thinne towards colpi margins, reticula
2	Craniotome versicolor Reichb.	-	17.5x14 µ	Psilate.
3	Lamium album Linn.	-	31 x 25 µ	-
4	Marrubium vulgare Linn.	Spheroidal	diameter 35 µ	-
5	Phlomis spectabilis Falc.	-	37 x 28 µ	-
6	P. purpurea Linn.	Prolate	38 x 25 µ	-
7	Stachys floccosa Benth	Prolate	35 x 21 µ	-
8	S.melissaefolia Benth.	Spheroidal	diameter 25 µ	granulose
9	S. sericea Wall.	-	32 x 25 µ	granulose

10	Teucrium quadrifarium Buch-Ham.	Prolate	48 x 28 µ	Colpi membrane crustate throughout its length
11	Elsholtzia cristata Willd.	6-zonocolpate sub-prolate	40 x 32 µ	Very thin faintly reticulate
12	E.polystachya Benth.	sub-oblate	17.5x21 µ	Psilate
13	Mentha arvensis Linn.	-	25 x 21 µ	-
14	Nepata erecta Benth.	-	45 x 34 µ	-
15	N. floccosa Benth.	Spheroidal	diameter 28 µ	-
16	N. eriostachys Benth.	-	32 µ	-
17	N. govaniana Benth.	Prolate	42 x 39 µ	-
18	N. Leucophylla Benth.	-	30 x 24 µ	-
19	N. raphanorhiza Benth.	Prolate, spheroidal	30 x 27 µ	-
20	N. spicata Benth.	-	34 x 28 µ	-
21	Origanum vulgare Linn.	Spheroidal	diameter 34 µ	-
22	Plectranthus rugosus Wall.	-	40 x 32 µ	-
23	P. ternifolium D. Don.	-	28 x 32 µ	-
24	Salvia coccinea Juss ex Murr.	Oblate	33 x 45 µ	-
25	S. glutinosa Linn.	-	32 x 43 µ	-
26	S. Lanata Roxb.	Prolate	49 x 35 µ	-

27	S. moorcroftiana Wall.	-	52 x 42 μ	-
28	Scutellaria repens Buch-Ham.	Spheroidal	diameter 18 μ	-

Rao and Shukla (1975) have grouped the plants on the basis of the apertural characters of the pollen grains. In Labiatae, the pollen grains are of two types : 3-zonicolpate and stephanocolpate. The 3-zonicolpate type of pollen grains are found in Ajuga bracteosa, Anisomeles ovata and Leucaus aspera. However, stephanocolpate type of pollen grains are reported in Anisochilus carnosus and Ocimum basilicum. The various characters of the pollen grains of Labiatae observed by Rao and Shukla (1975) are presented in the following table.

S.No.	Plant	Size	Shape	Colpi	Exine	Lumina	Shedding
1	Ajuga bracteosa Benth.	41 x 28 µ; range 32-48x20-36 µ	Ambicircular	Distinct, margins wavy, end pointed, Acolpium diameter 4 µ	1.5 µ thick	-	at 2-celled stage
2	Anisomeles ovata R. Br.	37 x 34 µ; range 32-40x20-36 µ	Prolate spheroidal	Acolpium 8 µ	Thinner near colpi margins, areolate	-	at 2-celled stage
3	Leucas aspera Link enum.	31 x 25 µ; range 28-32x16-32 µ	Sub-prolate	Colpi and acute	faveolate	Lumina small and circular	at 2-celled stage
4	Anisochilus carnosus Wall.	40 x 36 µ; range 44-48x28-44 µ	Sub-prolate	6(7) colpate, colpi ends sharply pointed, apocolpium diameter 8 µ	1.5 µ thick, faintly reticulate	-	at 2-celled stage
5	Ocimum basilicum Linn.	48 x 47 µ;	Prolate spheroidal	5(6) colpate colpi 8 µ wide, apocolpium, diameter 24 µ.	retipilate	lumina being larger	at 3-celled stage

MEGASPORANGIUM

The ovules in Labiatae are anatropous, unitegmic and tenuinucellate (See Davis, 1966). The anatropous ovules have been reported in Physostegia (Sharp, 1911), Monarda fistulosa, M. didyma, M. punctata, Nepata cataria (Bushnell 1936), Ocimum sanctum, O. canum, O. basilicum (Murthy, 1940), Anisomeles malabarica, A. indica (Murthy, 1942, 1946), Ocimum adscendens (Murthy, 1946), A. indica (Jaitly, 1966), Salvia splendens and S. coccines (Jaitly, 1972). However, the ovules are campylotropous in Leonurus (Ganguly, 1948).

The ovular primodium arises as an erect outgrowth and consists of a homogenous mass of parenchymatous cells. The meristematic cells divide with a rapid rate and due to unilateral growth, the ovules acquire anatropous configuration (Fig. 34 and 35). The first indication of the development of the ovule is noted in the epidermis and 3-4 layers of the sub-epidermal cells, which are rich in cytoplasm and contain conspicucus nuclei. Group of cells called ovule initials differentiate from this sub-epidermal tissue and are distinguished from the rest of the cells by their marked activity. They divide first more actively in one direction and the tissue, thus produced begins to elongated To keep pace with the activity of the sub-epidermal tissue, the epidermal cells also divide repeatedly anticlinally.

The epidermis of the placenta has its evenness at ovules and becomes apparent. In anatropous conditon the micropyle comes to lie close to the funiculus due to unilateral growth of the ovule.

According to Ganguly (1948) in Leonurus the ovule curves along the funicle as well as its lower portion and curvature is continued upto the tetrad stage consequently. This brings about a somewhat campylotropous conditon which is more apparent in the mature stage of the gametophyte (Fig. 38-41). Junell (1937) has figured such forms in Physostegia, Sideritis and Notochaete.

The nucellus is the earliest tissue to be differentiated and the integument envelops it later. The archesporial cell is hypodermal and functions directly as megaspore mother cell. The young ovule grows rapidly while the megaspore mother cell is elongating. The single integument finally encloses the nucellus. The tenuinucellar ovules are reported in Monarda fistulosa, M. didyma, M. punctata, Nepata cataria (Bushnell, 1936), Ocimum adscendens Anisomeles indica, A. malabarica (Murthy, 1946), A. indica (Jaitly, 1966), Salvia splendens and S. coccinea (Jaitly, 1972). The nucellar cells are reported to be uninucleate in Anisomeles (Jaitly, 1966) and not 2-3 nucleate as reported by Ganguly (1948). The nucellus is consumed by the time the embryo reaches 4-nucleate stages.

The integumental tissue develops after the archesporial cell is well differentiated. It first appears as an annular out growth from the base of the nucellus. The integument almost overtops the nucellus before the meiosis in megaspore mother cell is completed (Fig. 42). The ovule has a single massive integument in Physostegia (Sharp, 1911), Monarda fistulosa M. didyma, M. punctata, Nepata cataria (Bushnell, 1936), Ocimum sanctum, O. canum, O. basilicum (Murthy, 1940), Anisomeles malabarica, A. indica, O. adscendens (Murthy, 1946), A. indica (Jaitly, 1966), Salvia coccinea and S. splendens (Jaitly, 1972). The single integument of Anisomeles indica (Jaitly, 1966) is reported to be 8-9 layered.

The innermost layer of the cells of the integument begins to differentiate as endothelium or integumentary tapetum at the time when the megaspore mother cell initiates its activity. The endothelium is specialised to perform the nutritive function for the embryosac. It is present on either side of the embryosac. It may differentiate even before the disorganization of the nucellus. The presence of the endothelium enclosing the embryosac is a characteristic feature of most of the sympetalae. The endothelium is mainly found in tenuinucellate ovules. The integumentary tapetum has been reported in Monarda punctata, M. didyma, M. fistulosa and Nepata cataria (Bushnell, 1936). Except in Lallemantia iberica, Salvia

greggii, S. leucantha and S. splendens an endothelium differentiates but the extent to which it encloses the embryo sac varies (See Davis, 1966). Endothelium is usually single layered.

The hypostase tissue is very prominent in Monarda fistulosa, less prominent in M. didyma and Nepata cataria and not so conspicuous in M. punctata (Bushnell, 1936). Just at the level of the origin of the integument and directly below the embryo sac, there is a well-defined, but an irregular outlined group of nucellar cells which are usually poor in cytoplasmic contents but partially lignified or suberized walls composed of a highly refractive material. This patch of cells is called hypostase. According to Van Tieghem (1901) the hypostase forms a sort of barrier or boundary for the growing embryosac and prevents it from pushing into the base of the ovule. Johansen (1928) reported that it stabilises the water balance of resting seeds over the long period of dormancy during the hot, dry seasons. According to Venkata Rao (1958) it facilitates the rapid transport of food materials.

The funicular obturator has been reported in Anisomeles (Murthy, 1942, 1946), Ocimum basilicum, O. adscendens, O. sanctum, O. canum (Murthy, 1940, 1946), Anisomeles, Leonurus (Ganguly, 1948), A. indica (Jaitly, 1966), Salvia coccinea and S. splendens (Jaitly, 1972). The funiculus enlarges during the growth of the ovule and forms an obturator which

tightly fits against the micropylar region (Figs. 36 and 37). The obturator in Orthosiphon stamineus (Murthy, 1947) does not show differentiation into several types as in Anisomeles (Murthy, 1946), where the sub-epidermal cells of the obturator facing the micropyle elongate and become lignified. The chief function of the obturator is guiding the pollen tubes towards the micropyle.

Explanation of Figures

Fig. 34. *Anisomeles malabarica*; Section of ovule showing the integument, nucellus and archesporial cell (After Murthy, 1946).
Fig. 35. *Ocimum adscendens*; Section of ovule (After Murthy, 1946). Fig. 36-37. *Anisomeles indica*, Development of the obturator (obt) and integuments (After Ganguly, 1948). Fig. 38-41 *Leonurus sibiricus*; Stages showing the curvature of the ovule, development of integuments and obturator (obt). Fig. 42. *L. sibiricus*; Initiation of integuments (After Ganguly, 1948).

MEGASPOROGENESIS

The female archesporium is hypodermal in origin and is distinguished from the rest of the cells by its dense cytoplasm and prominent nucleus. The female archesporium is generally single-celled in Physostegia (Sharp, 1911), Salvia glutinosa, S. pratensis (Schnarf, 1931), Monarda fistulosa, M. didyma, M. punctata, Nepata cataria (Bushnell, 1936), Salvia mellifera, S. splendens, S. greggii, S. leucantha, S. apiana, S. columbarie (Carlson and Stuart, 1936), Anisomeles indica, A. malabarica, Ocimum adscendens (Murthy, 1946), Salvia, Hyptis, Ocimum, Mentha, Leucas (Jaitly, 1966), Salvia, coccinea, S. splendens (Jaitly, 1972), and Leucas procumbens (Satyanarayana, 1985).

The occurrence of multicelled female archesporium has also been reported in the family Labiatae. Schnarf (1917) and Strasburger (1879) have noted the presence of two archesporial cells in Galeopsis pubescens and Lamium respectively. The development of two megaspore mother cells has been recorded by Jamell (1937) in pogostemon patchouli, where two tetrads were developing side by side. The occurrence of two megaspore mother cells has also been recorded either superimposed or lying side by side in Leonurus (Ganguly, 1948). In Leonurus (Ganguly, 1948), a number of cases of multiple archesporium have also been observed (Fig. 43). In one

instance, six archesporial cells have been observed, and among these the upper two are slightly larger. From the double and multiple archesporium in Leonurus (Ganguly, 1948) double mother cells and double tetrads are formed, out of which only chalzal megaspores developed into the characteristic twin embryosacs (Fig. 44, 45 and 48). Junell (1937) has reported the presence of the potential archesporial cells in Molucella and Pogostemon around the base of the megaspore mother cells.

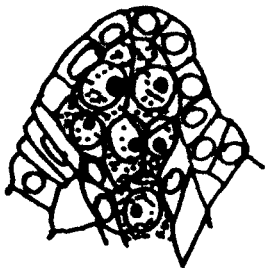
The archesporial cell directly functions as the megaspore mother cell in the tenuinucellate ovules. The archesporial cell grows rapidly and is markedly elongated at the time when its nucleus goes into synapsis preceding the first division (Fig. 46). The cell which on account of the occurrence of the heterotypic prophases in its nucleus is to be regarded as the megaspore mother cell, which by two successive divisions gives rise to linear megaspore tetrad (Fig. 47, 50 and 51). The formation of linear tetrad is reported in Salvia mellifera (Carlson and Stuart, 1936), Monarda fistulosa, M. didyma, M. punctata, Nepata cataria (Bushnell, 1936), Ocimum adscendens, Anisomeles indica, A. malabarica (Murthy, 1946) and Leucas procumbens (Satyanarayana, 1985).

An abnormal case of dyad and tetrad one partly overlying the other has been observed in Anisomeles (Ganguly, 1948) (Fig. 52). The tetrad is fully formed while the

dyad is just organised. This appears to have developed from the differential growth of two megaspore mother cells lying side by side. In Leonurus (Ganguly, 1948), a triad and a tetrad were lying side by side (Fig. 49). In Leonurus (Ganguly, 1948), still more peculiar and complex organisation has been noted, in which there are ten megaspores arranged in an irregular fashion. Of these one of the lower most megaspores has developed into a four nucleate embryo sac without much enlargement of the latter, three are much larger than those in normal tetrad, while three are small and in different stages of degeneration and the remaining three are of intermediate sizes but not very healthy. The disintegration of the upper three megaspores of the linear tetrad takes place from below upwards in both Anisomeles and Leonurus (Ganguly, 1948). There is an irregular outline of the degenerating megaspore nucleus as the first indication of the process. The degeneration of the non-functional megaspores is not completed until the late two-nucleate stage in Leonurus (Ganguly, 1948).

Explanation of Figures

Fig. 43-49. Leonurus sibiricus; Fig. 43. Multiple archesporium. Fig. 44-45. Double megaspore mother cells. Fig.46. First division of megaspore mother cell. Fig. 47.Linear tetrad of megaspores enclosed by the integumentary tapetum. Fig. 48. Complex arrangement of a number of megaspores in two layers. Fig. 49. Triad overlying tetrad of megaspores (After Ganguly, 1948); Fig. 50. Salvia mellifera; Axial row of megaspores (After Carlson and Stuart, 1936). Fig. 51. Ocimum adscendens; Linear tetrad of megaspores (After Murthy, 1946). Fig. 52-53. Anisomeles indica; Fig. 52. Linear tetrad overlying dyad megaspore mother cell. Fig. 53. Dyad megaspore mother cell (After Ganguly, 1948).



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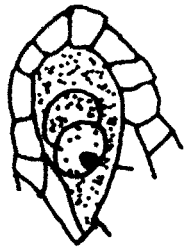

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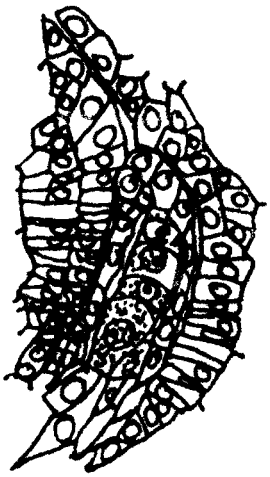

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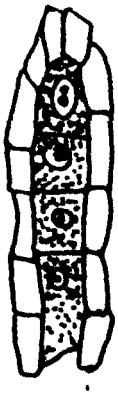

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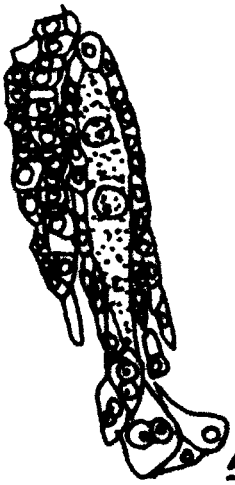

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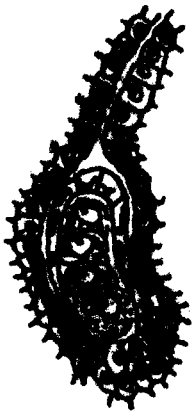

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FEMALE GAMETOPHYTE

The development of the female gametophyte in Labiatae conforms to the 8-nucleate monosporic and Polygonum type. Sharp (1911) for the first time recorded Polygonum type of embryo sac development in *Physostegia*. Later Ruttle (1931) in *Mentha* and *Lycopus*; Bushnell (1936) in *Monarda fistulosa*, *M. didyma*, *M. punctata* and *Nepeta cataria*; Carlson and Stuart (1936) in *Salvia mellifera*, *S. apiana*, *S. columbaria*, *S. splendens*, *S. leucantha* and *S. greggii*; Murthy (1940) in *Ocimum sanctum*, *O. canum* and *O. basilicum*; Murthy (1942) in *Anisomeles*, Murthy (1946) in *O. adscendens*, *Anisomeles indica* and *A. malabarica*; Murthy (1947) in *Orthosiphon stamineus*; Jaitly (1966) in *A. indica*; Jaitly (1969) in *Salvia*, *Hyptis*, *Ocimum*, *Mentha* and *Leucas*; Jaitly (1972) in *Salvia*, Kandelaki and Kobakhidze (1977) in *O. basilicum* and Satyanarayana (1985) in *Leucas procumbens* observed Polygonum type of embryo sac development.

The functional megaspore represents the beginning of the female gametophyte. The chalazal megaspore enlarges in size and develops terminal vacuoles. Usually one large vacuole appears on either side of the nucleus in the direction of the long axis of the cell. The nucleus of the functional megaspore divides mitotically forming a 2-nucleate embryo sac (Fig. 54). Both the nuclei remain at the centre but

as the embryo sac enlarges considerably the nuclei move towards opposite poles. Most of the cytoplasm is aggregated around the nuclei and the rest forms a thin peripheral layer, the centre being occupied by a large vacuole. The next division in the nuclei of the 2-nucleate embryosac gives rise to a 4-nucleate stage (Fig. 54, 55, 64, 65) which is followed by the 8-nucleate unorganized embryosac comprising a micropylar and a chalazal quartet. The embryosac consists of two synergids and an egg at the micropylar end, three antipodals at chalazal end and two polar nuclei at the centre (Fig. 62).

The three nuclei from the micropylar quartet form a well organized egg apparatus at the micropylar end of the embryo sac. Egg apparatus consists of an egg cell and two synergids (Fig. 63). The three cells of the egg apparatus are arranged in a triangular fashion. The egg cell hangs below the synergids. The egg cell shows common walls with the two synergids. The egg cell becomes highly polarised early in its development. The polarity is expressed by the aggregation of the cytoplasmic elements at the chalazal end of the cell. The micropylar end of the cell is occupied by a large vacuole. The cytoplasm seems to have reserve food materials. The distribution of the vacuole and the cytoplasm in the egg cell is just the opposite of that in the synergids.

The synergids are elongated cells present at the micropylar end of the embryo sac. Hooked and beaked synergids are

the characteristics of Labiatae (See Davis, 1966). The synergids are first found triangular in outline with dense cytoplasm and conspicuous nuclei at the base. They enlarge rapidly and become pear-shaped. The nucleus is gradually pushed towards the tip due to the formation of a large vacuole at the base of each synergid. In the investigated species the synergids have long acute beaks fitting into the micropylar end of the embryo sac. According to Coulter and Chamberlin (1903) this is a characteristic feature of the Sympetalae. The uniformity in the shape and size of the synergids suggests that they act as haustorial organs and probably help the fertilized egg and the primary endosperm nucleus in their nutrition. They also appear to have a mechanical function in leading the pollen tube to the egg. The hooked synergids are reported in Leonurus, Anisomeles (Ganguly, 1948), Mentha, Orthosiphon and Stachys (See Davis, 1966). Synergids are ephemeral structures. In Anisomeles (Ganguly, 1948), one synergid degenerates before the entry of the pollen tube into the embryo sac where as the other one, often called as persistent synergid degenerates shortly after the embryo sac has received the pollen tube discharge. The synergids play an important role in directing the pollen tube growth by secreting some chemotropically active substances (Ishikawa, 1918 and Pluijum, 1964). The degenerating synergid forms the seat for pollen tube discharge in the embryo sac.

There is a central cell with two polar nuclei. The polar nucleus from the chalazal end and the polar nucleus from the micropylar end migrate towards the centre. The polar nuclei are very large and each possesses a conspicuous nucleolus. The central cell is connected with the egg, synergids and the antipodals through plasmodesmatal connections. The fusion of the polar nuclei before or at the time of fertilization has appeared to be a general feature of Labiatae. Schnarf (1917) stated that the fusion of the polar nuclei before fertilization is a characteristic of Labiatae; but Junell (1937) mentioned the occurrence of the polar fusion at the time of fertilization in Lycopus europaeus, Mentha and Pogostmon. In ocimum adscendens, Anisomeles indica and A. malabarica (Murthy, 1946) the polar nuclei meet at the constricted region of the embryo sac and donot fuse until fertilization. According to Ganguly (1948), in Anisomeles they fuse at the time of the double fertilization. In Leonurus (Ganguly, 1948) they fuse before fertilization.

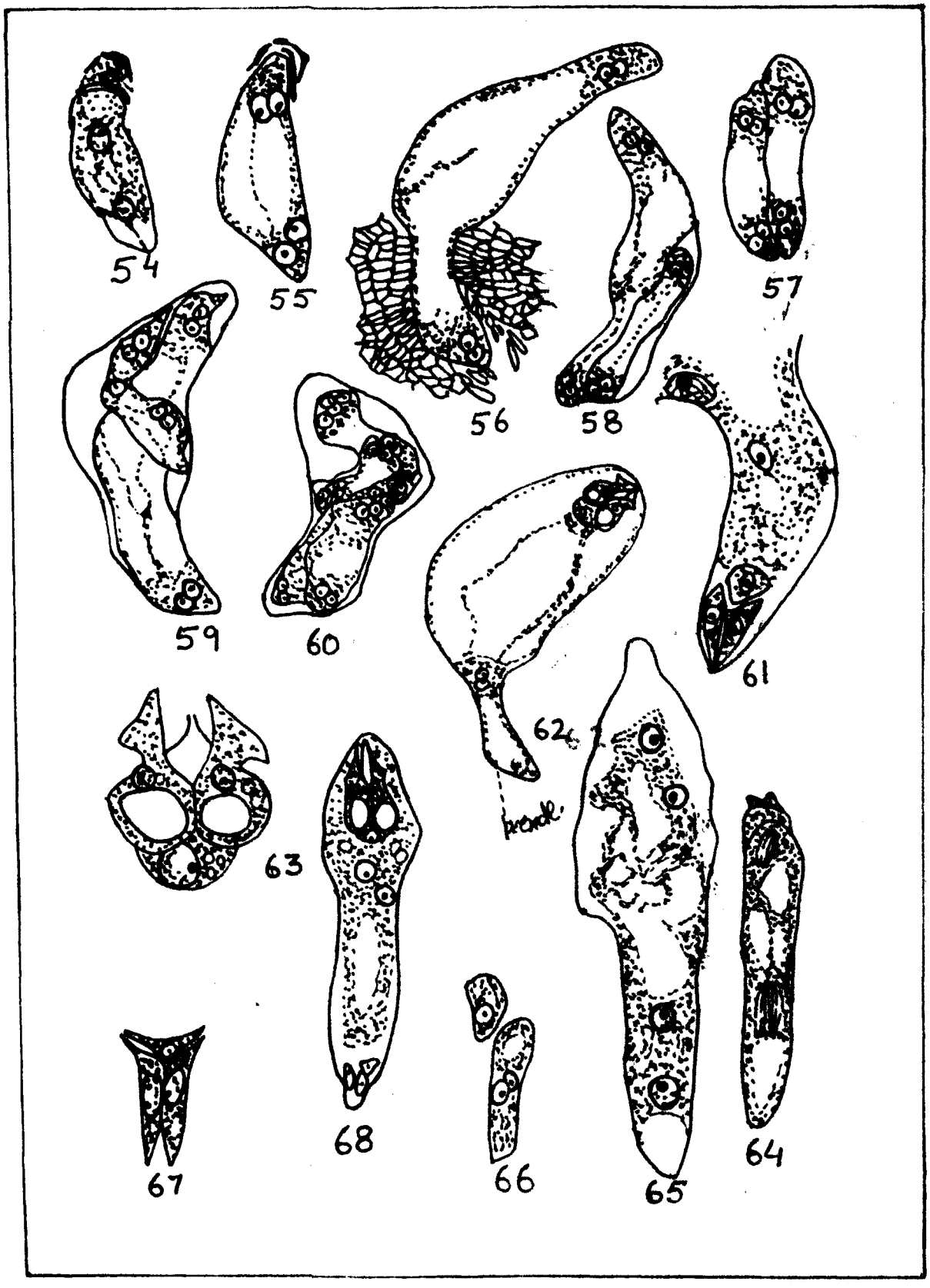
The three nuclei from the chalazal quartet form the three antipodals which fit into the chalazal groove of the embryosac (Figs. 61,57, 68). The antipodals which occupy the chalazal end of the embryo sac are three in number and incomspicuous in Labiatae. The antipodals are usually ephemeral (See Davis, 1966). Formation of a large number of antipodals has been observed in Physostegia virginiana

(Junell, 1937). In Anisomeles malabarica and A. indica (Murthy, 1946) one antipodal cell is comparatively larger than the other two. In Leonurus and Anisomeles (Ganguly, 1948) there are two long lower antipodal cells with a smaller one fitting into the narrow chalazal portion. In both the cases the antipodals degenerate very early and it is difficult to trace them in a mature embryo sac. The disintegration of the antipodal cells before fertilisation has also been noted by Schnarf (1917) and Bushnell (1936a). Junell (1937) has referred to the antipodals in Labiatae, as inconspicuous but that is probably because he found them in later stages when they generally degenerate. The degeneration of antipodals before fertilization has also been reported in Salvia officinalis and S. sclarea (Polishchuk, 1972). In O. adscendens (Murthy, 1946) the antipodals disappear after fertilization.

The embryosac is more or less straight in Anisomeles and L-shaped in Leonurus (Ganguly, 1948).

Double and multiple embryo sacs have been observed in Leonurus (Ganguly, 1948). In one case two embryo sacs each with a four nucleate gametophyte have been found, in which both the embryo sacs are almost of equal size (Fig. 57), one of them has just started to grow above the other. In other two instances, one of these four nucleate embryo sacs has grown considerably above the other which lags behind being pressed at the side by the former (Fig. 58 and 59).

In another case the smaller embryo sac lies at the micropylar part at the side of the larger sac and contains five nuclei-one pair at each of the two poles and one at the centre. The lower portions of this smaller embryo sac is, however, deflected on the larger one. The occurrence of two embryo sacs in the same ovule has also been observed in Salvia officinalis (Polishchuk, 1972). The two embryo sacs formed in one ovule are 7-cellular and bi polar. In Leonurus (Ganguly, 1948) two to five embryo sacs have developed side by side, one of them reaching upto eight nucleate stage. A multiple embryo sac is observed in Leonurus (Ganguly, 1948). There are three embryo-sacs in the upper broadened part and two in the lower (Fig. 60). Of the three in the upper one is an eight nucleate gametophyte with four nuclei at the two poles, and the other two are four nucleate each having two nuclei at the two poles, and the other two are four nucleate, each having two nuclei at the two ends; of the two nuclei at the lower end in each of the four embryo sacs, one has developed a cytoplasmic membrane forming an antipodal-like cell and the other remains free. The two embryo sacs in the chalazal portion are typically four nucleate. The development of more than one embryo sacs in the same ovule is generally due to simultaneous development of more than one megaspore mother cell which is a common feature in Leonurus (Ganguly, 1948).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POLLINATION AND COURSE OF POLLEN TUBE

The pollination in Labiatae is entomophilous or anemophilous.

There are usually four stamens in Labiatae. In Salvia and Lycopus two stamens are reduced to staminodes. In Salvia the two stamens are peculiarly constructed. Each stamen has a small filament and a big connective. Only a part of anther which remains in the curved region of the upper lobe is fertile, rest of it is sterile (Fig. 73). The sterile lobe is very small and remains attached to the filament. The whole structure forms a sort of lever mechanism, which helps in the process of pollination.

The bilipped corolla in Labiatae ensures that the visiting insect shall take a definite position in regard to the anthers and stigma. Most of the flowers are bee flowers. The long tubed red flowers of Monarda are butterfly flowers and a few species of Salvia are hummingbird flowers. Thymus, Origanum and their allies have nearly regular flowers visited by a more miscellaneous selection of insects (Willis, 1966). The flower in Lamium is homogamous which facilitates self-pollination. However, the flowers are dichogamous in Teucrium which facilitates cross-pollination. The lever mechanism of Salvia is almost

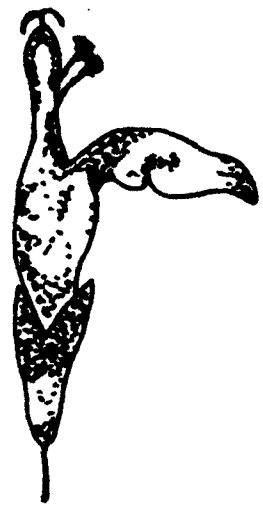
unique. The visiting insect alights on the lower lobe. When it moves in search of honey, it passes from the sterile lobe of the stamen. As soon as it comes on the smaller part of the connective, a pressure is created with the result that the upper portion bends downwards. The anther comes in contact with the dorsal part of the body of the insect and the pollen grains are dusted on its back. The carpel after maturity comes out of the upper lobe and its stigma bends downwards (Fig. 74). An insect laiden with pollen grains whenever visits such flowers, transfers the pollen grains to the stigma and thus pollination is accomplished.

The style in Labiatae is gynobasic (Fig. 71). The stigma is bilobed and is believed to play an important role in the germination of the pollen grains (Mathur, 1956). In Labiatae, the pollen grains get entangled between the stigmatic papillae where they absorb stigmatic secretion and send out pollen tubes. The pollen tubes enter the stigmatic tissue, grow down the stylar tissue through inter-cellular spaces without damaging them and finally reach the ovarian cavity, which is bilocular and find their way into the ovules through micropyle. This has been recorded in Ocimum sanctum, O. basilicum, O. canum (Murthy, 1940), O. adscendens (Murthy, 1946), Leonurus, Anisomeles (Ganguly, 1948), Mentha piperata (Admiral'skaya, 1960), Salvia splendens, S. coccinea (Jaitly

1972) and Leucas procumbens (Satyanarayana, 1984). After reaching the micropylar end, the pollen tube enters the embryosac destroying one of the synergids.

Explanation of Figures

Fig. 69-74. Salvia; Fig. 69. Flower; Fig. 70. L.S. of the flower; Fig. 71. L.S. of the carple showing gynobasic style; Fig. 72. Carpel; Fig. 73. Stamen showing connective, fertile and sterile anther lobes; Fig. 74. Pollination in the flower.



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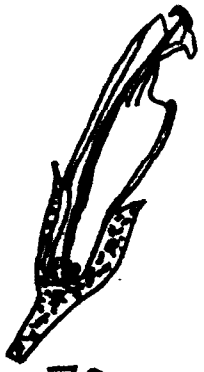

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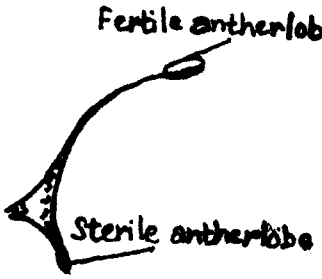

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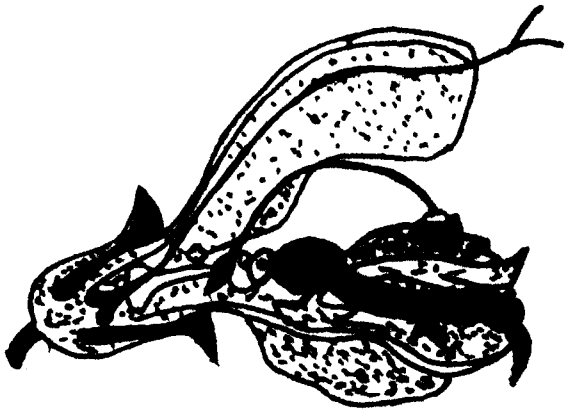

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FERTILIZATION

Fertilization is porogamous in the described Labiatae, viz., Ocimum sanctum, O. canum, O. basilicum (Murthy, 1940), Anisomeles, O. adscendens (Murthy, 1946), Leonurus, Anisomeles (Ganguly, 1948), Mentha piperata (Admiral'skaya, 1960), Salvia coccinea, S. splendens (Jaitly, 1972) and Leucas procumbens (Satyanarayana, 1985).

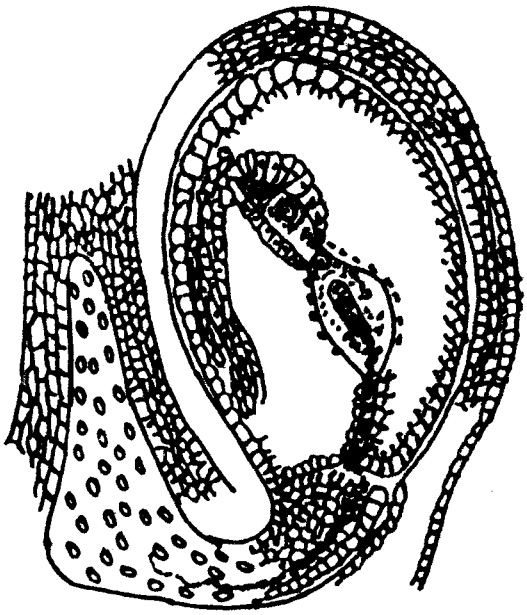
In Ocimum sanctum, O. canum, O. basilicum (Murthy, 1940), O. adscendens (Murthy, 1946), Anisomeles and Leonurus (Ganguly, 1948) the pollen tubes have been observed to travel along the obturator, the function of which is to direct the pollen tube towards the micropyle (Fig. 75 and 76). On reaching the micropylar opening, the pollen tube expands and progresses steadily until it reaches the tip of the embryo sac. One synergid is generally disorganised during the entry of the pollen tube into the embryo sac. The other synergid also degenerates during the act of fertilisation or soon after the fertilization. In Anisomeles indica and A. malabarica (Murthy, 1946), the embryo sac is characterised by the survival of one of the synergids which persists for sometime during endosperm development. In Leonurus and Anisomeles (Ganguly, 1948), the pollen tube passes through one of the synergids and discharges its content into it. Consequently, the synergids become dense

black in colour (Fig. 78 and 79). However, in Ocimum adscendens (Murthy, 1946) both the synergids are destroyed one after the other before fertilization.

The pollen tube is a delicate cylindrical structure prior to its entry into the embryo sac. It becomes quite conspicuous inside the embryo sac and bursts into the embryo sac releasing the male gametes in the vicinity of the egg apparatus. One male gamete fuses with the egg (Syngamy) while the other fuses with the two polar nuclei lying in the middle (triple fusion). This has been observed in Ocimum sanctum, O. canum, O. basilicum (Murthy, 1940), Anisomeles, O. adscendens (Murthy, 1946), Anisomeles, Leonurus (Ganguly, 1948), Mentha piperata (Admiral'skaya, 1960), Salvia comminea, S. splendens (Jaitly, 1972) and Leucas procumbens (Satyanarayana, 1985).

In one instance, in Anisomeles indica (Ganguly, 1948), it has been found that double fertilization precedes syngamy. It was found that the male gamete had not yet reached the egg, though the second one was in the state of fusion. This also suggests the possibility that the male gamete which was found at the lowermost portion of the black synergid travelled down quickly and united with the fusing polar nuclei before the other nucleus could reach the egg.

In Ocimum basilicum (Kandelaki and Kobakhidze, 1977), the fertilization occurs within 3-4 hours of pollination.



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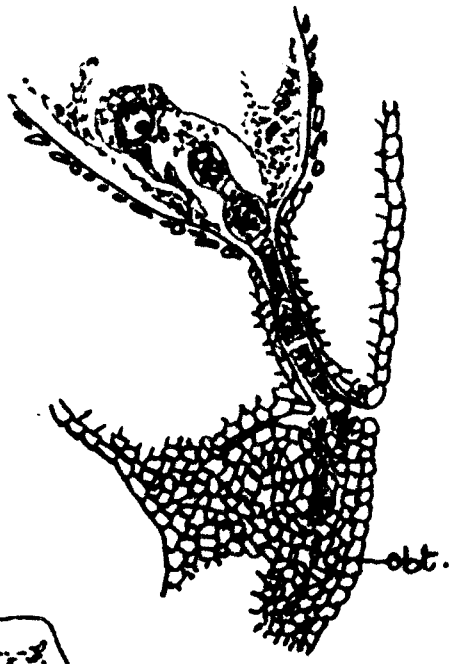

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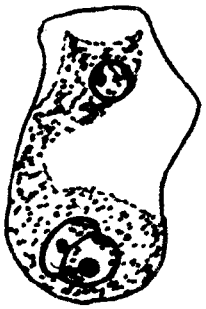

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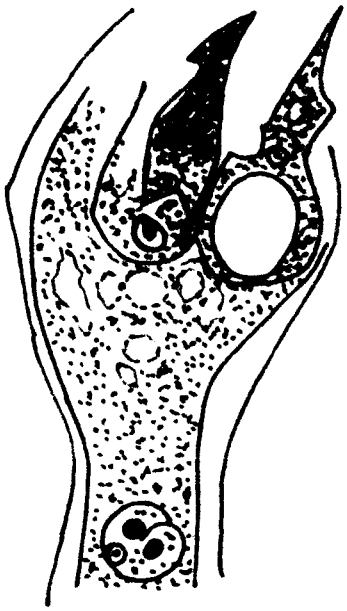

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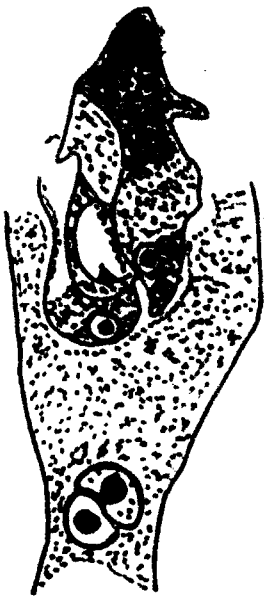

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Explanation of Figures

Fig. 75-76. *Ocimum adscendens*; pollen tube passing through conductive tissue and penetrating the obturator (After Murthy, 1946).

Fig.77. *Leonurus sibiricus*; Fertilization.

Fig. 78-79. *Anisomeles indica*; stages of fertilization and triple fusion latter preceding syngamy (After Ganguly, 1948).

ENDOSPERM

Development of the endosperm in Labiatae is Cellular and has been reported in Lamium amplexicaule, Stachys Palustris, Mentha canadensis, Salvia lanceolata, Physostegia virginiana, Salvia azurea, Leonurus Cardiaca, Monarda fistulosa, Bruella vulgaris, Nepata cataria, Tenericum canadense, Dracocephalum, Phyenanthemum lanceolatum, Scutellaria parvula, Lycopus rubellus (Billings, 1909), Physostegia galericulata, Brunella vulgaris, Salvia glutinosa, S. Pratensis, Galeopsis speciosa, Thymus ovatus, Mentha austriaca, Satureja acimos (Schnarf, 1917, 1931), Mentha (Ruttle, 1931), Salvia mellifera, S. apiana, S. columbarie , S. splendens, S. leucantha, S. greggii (Carlson and Stuart, 1936), Prostanthera lasianthos, Amethystea paryula, Hyptis pectinata (Junell, 1937), Ocimum sanctum, O. canum, O. basilicum (Murthy, 1940), Leucas aspera (Murthy, 1941 a), Anisomeles indica, A. malabarica (Murthy, 1942, 1946 b), O. adscendens (Murthy, 1946), Orthosiphon stamineus (Murthy, 1947), A. indica, Leonurus sibiricus (Ganguly, 1948), Brystropogon origanifolius (Crete, 1963 b), A. indica (Jaitly, 1966), Mentha piperata (Jaitly, 1968), Pogostemon, Salvia, Hyptis, Ocimum (Jaitly, 1969), Salvia coccinea, S. splendens (Jaitly, 1971, 1972), Lavandula spica (Polishchuk and Dzevaltovs'kyl, 1972), O. basilicum (Kobakhidze, 1976), Scutellaria violacea, S. galericulata,

Coleus, Westringia, Dysophylla, Ocimum, Calamintha, Meriandra, Hyptis, Ajuga, Nepata, Leucas, Geniosporum, Lavandula, Salvia, Leonotis, Perilla (Kumari, 1976), O. basilicum (Kandelaki and Kobakhidze, 1977) and Leucas procumbens (Satyanarayana, 1985).

The development of endosperm starts more or less immediately after fertilization, while the division of the zygote is delayed unless sufficient amount of endosperm is formed. In Mentha piperata (Admiral'skyaya, 1960) the first division of the endosperm cell begins 7 hourse after pollination. The first division of the primary endosperm cell is transverse in Physostegia (Sharp, 1911), Scutellaria galericulata, Salvia glutinosa, S. pratensis, Galeopsis speciosa, Brunella vulgaris (Schnarf, 1917 b), Salvia mellifera, S. apaiana, S. splendens, S. greggii, S. leucantha, S. columbarie (Carlson and Stuart, 1936), Prostanthera lasianthosa, Amethystea parvula, Hyptis pectinata, Scutellaria galericulta (Junell, 1937), Leucas aspera (Murthy, 1941 a), Anisomeles indica, A. Malabarica (Murthy, 1942), Ocimum adscendens (Murthy, 1946), Orthosiphon stamineus (Murthy, 1947), Anisomeles, Leonurus Sibiricus (Ganguly, 1948), Mentha piperata (Admiral'skaya, 1960), A. indica (Jaitly, 1966), Salvia coccinea, S. splendens (Jaitly, 1971), Coleus, Scutellaria, Westringia, Dysophylla, Ocimum, Calamintha, Meriandra, Hyptis, Ajuga, Nepata, Leucas, Geniosporum, Lavandula, Salvia, Leonotis, Perilla (Kumari, 1976) and Leucas procumbens (Satyanarayana, 1985).

Considerable variations have been noticed in the sequence of cell divisions in the early stages of endosperm development Depending on the sequence of division four main types Scutellaria, Brunella, Stachys and Galeopsis are recognized (Schnarf, 1917).

In Scutellaria type, the second division in both the endosperm chambers is longitudinal resulting in four uni-nucleate cells. This followed by a transverse division resulting in a single tiered micropylar and chalazal chambers and two tiered central endosperm. Scutellaria type of endosperm development is reported in Scutellaria galericulata (Schnarf, 1917 b), Prostanthera lasianthos, Amethystea parvula (Junell, 1937), Anisomeles indica A. malabarica (Murthy, 1946b). Scutellaria violacea and Westringia rigida (Kumari, 1976).

In Brunella type, the second divison in the micropylar cell is longitudinal resulting in two uni-nucleate cells while the division in the chalazal cell is free nuclear. This has been reported in Brunella vulgaris, Salvia glutinosa, S. pratensis (Schnarf, 1917 b), Hyptis pectinata (Junell, 1937), Salvia, Mentha, Pogostemon (Jailty, 1969), Salvia coccinea S. splendens (Jaitly, 1972), Dysophylla and Salvia (Kumari, 1976).

In stachys type, the divisions in the chalazal cell are free nuclear, while the micropylar endosperm chamber divides transversely. This type of endosperm development has been reported in Hyptis, Ocimum, Leucas (Jaitly, 1969),

procumbens and Hyptis (Kumari, 1976).

Ajuga, Leucas. The fourth type of endosperm formation in Labiatae is Galaeopsis type (Schnarf, 1917 b). It differs from Brunella type. Here division in both the primary endosperm cell is not simultaneous. The basal cell divides comparitively early. Free nuclear divisions occurs in the basal cell This type has been reported in Galaeopsis speciosa (Schnarf, 1917 b).

More than one type of endosperm development may occur in different species of some genera like Salvia, Leonurus and Anisomeles (Kumari, 1976).

The occurrence of haustoria is a common feature of cellular endosperm. The haustoria may be micropylar or chalazal. Occasionally, both types of haustoria are present in the same plant. The upper most large micropylar cell or cells of the three tiered endosperm appears to take the micropylar haustorial function. The micropylar haustorium shows some difference in its structure as well as in the degree of its aggressiveness. A number of cell divisions occur in the 2 apical cells. So the region of the haustorium becomes filled with cellular tissue. The cells are large, thin walled and vesicular (Fig. 90-94, 102 and 104). The cellular micropylar haustorium is recorded in Salvia glutinosa, S. pratensis (Schnarf, 1917 b), Anisomeles indica, A. malabarica (Murthy, 1946 b), Hyptis, Mentha, Ocimum, Salvia, Leucas (Jaitly, 1969), Westringia rigida, Anisomeles, Salvia, Ajuga bracteosa, Meriandra bengalensis, Nepeta hindostana, Calamintha umbrosa, Leonotis

nepetaefolia, Lavandula vera, Geniosporum Hyptis, Ocimum, Plectranthus incanus, Killimandscharicum, Perilla Ocimoides, Leucas mollissima, L. aspera (Kumari, 1976) and L. procumbens (Satyanarayana, 1985). The multicellular micropylar haustorium of Scutellaria galericulata and Amethystea parvula (Junell, 1937) represents the most primitive condition. Here the two cells of the terminal tier of the 3-tiered endosperm are completely used up in the formation of the micropylar haustorium. 2-celled micropylar haustorium has also been reported in Pogostemon, Anisomeles (Jaitly, 1969) and Dysophylla (Kumari, 1976). In Pogostemon (Jaitly, 1969), each cell of the 2-celled micropylar haustorium is 2-nucleate. In Anisomeles and Leonurus (Ganguly, 1948) the the uppermost tier of the 3-tiered stage is not directly transformed into the micropylar haustorium but divides again, the product being a portion of endosperm and haustorial cells (Figs. 84, 85 and 86). 4-celled micropylar haustorium has been reported in Anisomeles malabarica (Murthy, 1942, 1946b). In A. indica (Kumari, 1976) the micropylar haustorium is 2-3 tiered. While in Westringia rigida (Kumari, 1976) it is biseriate and comprises more than 5 tiers of the cells. In A. indica (Murthy 1946 b; Ganguly, 1948) the micropylar hasutorium is 6-10 celled.

The number of nuclei also varies in the micropylar haustorium of different genera, viz., 2-nucleate in Ocimum, Mentha, Salvia (Jaitly, 1969), Salvia coccinea, S. splendens (Jaitly, 1971), Salvia, Westringia rigida, Amethystea parvula, Ajuga

bracteosa, Meriandra bengalensis, Nepata hindostana (Kumari, 1976), 4-nucleate in Orthosiphon stamineus (Murthy, 1947), Leonotis nepetaefolia Lavandula vera, Geniosporum (Kumari, 1976), 8-nucleate in Leucas cephalotes (Jaitly, 1969), Perilla ocimoides, Leucas mollissima (Kumari 1976), 12-19 nucleate in Leucas aspera (Kumari, 1976) and 16-nucleate in Leonurus sibiricus (Ganguly, 1948) Fig. 98 and 99). The different characteristics of the micropylar haustorium has been recorded in the following table:

S.No.	Name of the Plant	No. of cells	No. of nuclei
1.	Anisomeles malabarica	2- 4 celled	--
2.	Pogostemon	2 celled	Each cell being 2-nucleate
3.	A. indica	6-10 celled	--
4.	Ocimum	--	2- 5 nucleate
5.	Mentha	--	2 nucleate
6.	Salvia	--	2 nucleate
7.	S. splendens	--	2 nucleate
8.	Westringia rigida	--	2 nucleate
9.	Amethystea parvula	--	2 nucleate
10.	Ajuga bracteosa	--	2 nucleate
11.	Meriandra begalensis	--	2 nucleate
12.	Nepata hindostana	--	2 nucleate
13.	Orthosiphon stamineus	--	4 nucleate
14.	Leonotis nepetaefolia	--	4 nucleate
15.	Lavandula vera	--	4 nucleate
16.	Geniosporum	--	4 nucleate
17.	Hyptis	--	5 nucleate
18.	Plectranthus incanus	--	5 nucleate
19.	Killimandscharium	--	5 nucleate
20.	Leucas cephalotes	--	8 nucleate

21.	L. mollissima	--	8 nucleate
22.	Perilla ocimoides	--	8 nucleate
23.	Leucas aspera	--	12-19 nucleate
24.	Leonurus sibiricus	--	16 nucleate

In Thymus ovatus, Mentha austriaca, Satureja acimos and Salvia pratensis the micropylar haustorium shows an irregular outline with a caecum like lateral growth into which the nuclei migrate (Schnarf, 1917 b).

The cytoplasm in the cells of the micropylar haustorium of Anisomeles and Ocimum adscendens (Murthy, 1946) is reported to be fibrous in appearance and is densest along the periphery. Varying numbers of refractive bodies which stain greenish-yellow with haematoxylin, are present in the spherical stages of the nucleolus. The nuclei of the haustorium are spherical in the early stages but soon become elliptical. The nucleolus is also spherical in early stages but later on assumes various shapes. The nuclear reticulum is very distinct and is composed of a system anastomosing strands with chromatic swellings arranged uniformly. The micropylar haustorium is active upto a very late stage in the development of the embryo, its contents being absorbed finally by the central endosperm tissue.

The chalazal haustorium functions in the early stages of endosperm development and attains its maximum development when the endosperm is only a few celled (Fig. 103 and 105).

It is broader in the upper portion and gradually tapers downwards. It elongates to a certain extent towards the vascular trace and sends in sucker like haustorial branches into the cells below which appear empty in contrast to the surrounding rich cells of the vascular trace.

The chalazal haustorium has been recorded either 2 celled or bi-nucleate (Fig. 95). 2-celled chalazal haustorium is reported in Scutellaria galericulata (Schnarf, 1917 b), Anisomeles (Murthy, 1942, 1946), A. indica (Ganguly, 1948; Jaitly, 1966) and sometimes in Leonurus sibiricus (Ganguly, 1948). However, bi-nucleate chalazal haustorium has been recorded in Pogostemon patchouli, Elsholtzia cristata (Junell, 1937), Orthosiphon staminens (Murthy, 1947), Leonurus and occasionally in Anisomeles indica (Ganguly, 1948), Hyptis, Salvia, Pogostemon, Mentha, Leucas (Jaitly, 1969), Salvia splendens, S. coccinea (Jaitly, 1972), Westringia rigida and Amethystea (Kumari, 1976). As deviations from the normal two celled or the less occurring bi-nucleate chalazal haustorium, a three-nucleate two-celled chalazal haustorium (one of the cells being bi-nucleate) and an absolutely uni-nucleate chalazal haustorium were noticed as rare cases in Anisomeles indica (Ganguly, 1948) (Fig. 89). 4-nucleate chalzal haustorium is found in Ocimum adscendens (Kumari, 1976).

The variations in the features of the chalazal haustorium have been recorded in the tabular form:

S.No.	Name of the Plant	No. of cells	No. of nuclei
1.	Scutellaria galericulata	2-celled	--
2.	Anisomeles indica	2-celled	rarely uni-nucleate or 3-nucleate
3.	A. Malabarica	2-celled	occassionally 2-nucleate and rarely 3-nucleate
4.	Leonurus sibiricus	rarely 2-celled	2-nucleate
5.	Orthosiphon stamineus	--	2-nucleate
6.	Hyptis	--	2-nucleate
7.	Leucas	--	2-nucleate
8.	Pogostemon	--	2-nucleate
9.	Mentha	--	2.nucleate
10.	Salvia coccinea	--	2-nucleate
11.	S. splendens	--	2-nucleate
12.	Westringia rigida	--	2-nucleate
13.	Amethystea	--	2-nucleate
14.	Elsholtzia cristata	--	2-nucleate
15.	Pogostemon patchouli	--	2-nucleate
16.	Ocimum adscendens	--	4-nucleate.

In Lavandula multifida, Lallemantia iberica and Hormium Pyrenaicum the chalazal haustorium shows a prominant caecum (Junell, 1934). In Plectranthus incanum the chalazal haustorium shows some lateral extensions (Kumari, 1976).

The cytoplasm of the cells of the chalazal haustorium has a fibrous appearance and stains densely with haematoxylin. Their large nuclei show conspicuous nuclei. In Ocimum adscendens (Murthy, 1946), the chalazal haustorium is bi-nucleate in the younger stages which later fuse into one. The resulting single nucleus reveals a coarse reticulate structure. Numerous starch grains are present in the chalazal haustorium of O. adscendens (Murthy, 1946). As the haustorium progresses towards the vascular trace it expands into a bulbous structure and terminates by sending two branches, one reaches the integument and the other penetrates the vascular trace. After a considerable period of activity the hasutorial cells disintegrate and an empty canal is left behind.

There are few members of Labiatae which have both the chalazal and the micropylar haustoria cellular. This has been reported in Westringia (Billings, 1909; Kumari, 1976), Leucas aspera (Murthy, 1941), Anisomeles malabarica, A. indica, Ocimum adscendens (Murthy, 1946), Orthosiphon stamineus (Murthy, 1947), Anisomeles, Leonurus (Ganguly, 1948), A. indica (Jaitly, 1966), Salvia coccinea, S. splendens (Polishchuk, 1972) and Leucas procumbens (Satyanarayana, 1985).

Sometimes the coenocytic haustorium is also found in Labiatae. The coenocytic haustorium is formed either by the break down of incipent cell plates (Junell, 1937) or by free nuclear divisions (Billings, 1909, Sharp, 1911) or by

both (Kumari, 1976). The coenocytic micropylar haustorium is reported in Scutellaria (Billings, 1909; Kumari, 1976). The coenocytic chalazal haustorium is reported in Mentha, Pogostemon, Salvia, Hyptis, Leucas and Ocimum (Jaitly, 1969).

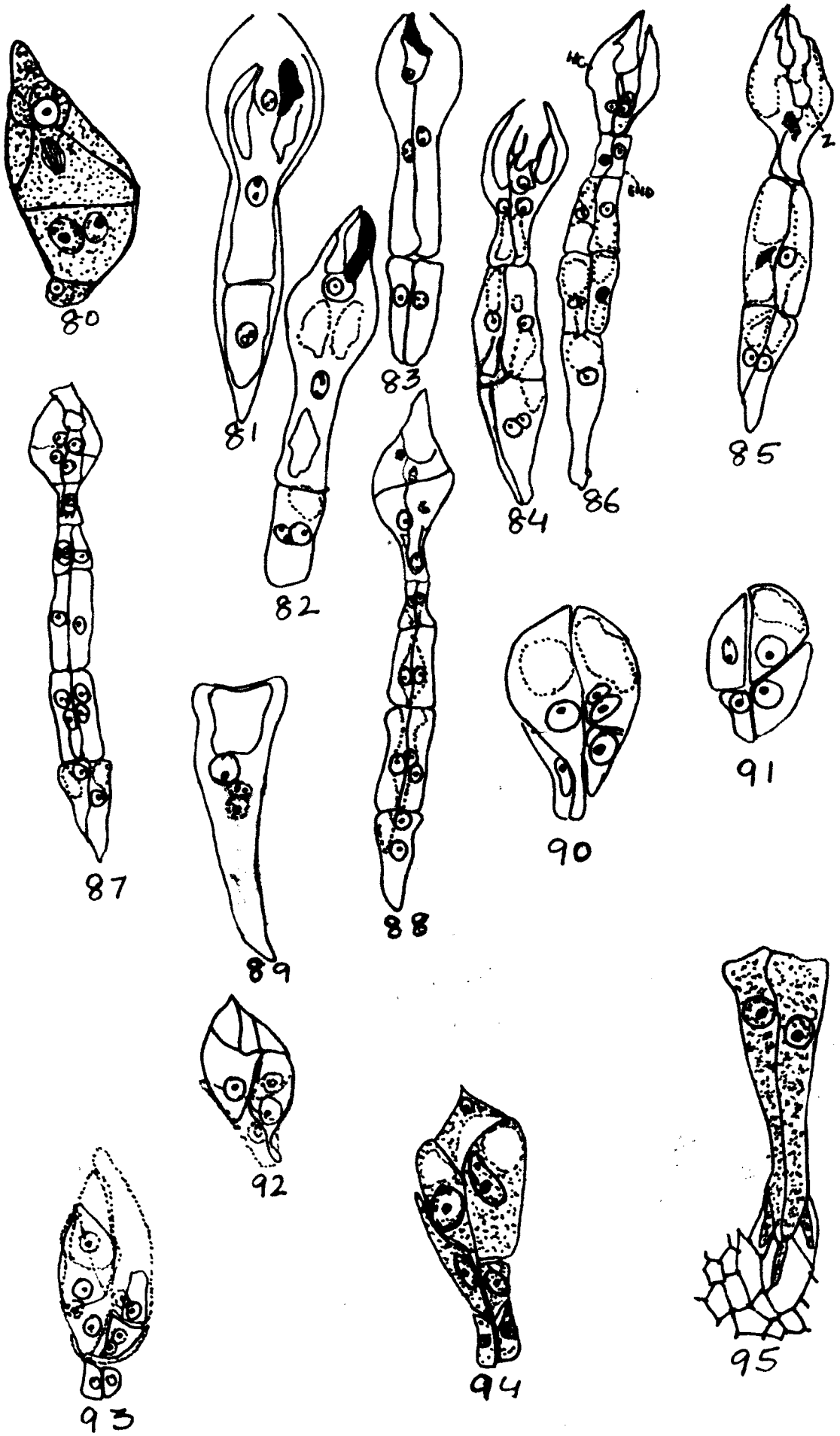
According to Kumari (1976) in Ocimum, Calamintha, Meriandra Hyptis, Ajuga, Leucas, Nepata, Geniosporum, Lavandula, Salvia, Leonotis and Perilla both the micropylar and the chalazal haustoria are coenocytic. The coenocytic haustorium is more aggressive and effective in function. In Dysophylla (Kumari, 1976) the chalazal haustorium is coenocytic where as the micropylar haustorium is cellular. But in Scutellaria (Billings 1909) the chalazal haustorium is reported to be cellurlar and the micropylar haustorium is coenocytic.

The development of endosperm in Brystropogon origanifolius (Crete, 1963) is characterised by a strong digestive activity of the chalazal and the micropylar haustoria. The development of the endospermous tissue in the early stages extends towards the chalazal part of the ovule where a large amount of the chalazal tissue is absorbed (Fig. 100). The activity of the chalazal haustorium is of short duration and an empty haustorium is left behind. When the chalazal haustorium is absorbed, the micropylar haustorium is very actively digesting the micropylar tissue. The further

development of endosperm extends towards the micropylar part of the ovule gradually obliterating the micropylar haustorium. Finally the micropylar haustorium becomes empty giving place to the advancing endosperm tissue, which later occupies most of the ovule.

Explanation of Figures

Fig. 80. *Salvia splendens*; Young endosperm. First division of primary endosperm nucleus in transverse. Uppermost nucleus is of the zygote and the lowermost an antipodal (After Carlson and Stuart, 1936). Fig. 81-95. *Anisomeles indica*; Fig. 81-88. Showing stages in the formation of endosperm and haustoria. Only outlines of cells and nuclei represented; vacuoles shown with dotted lines. Fig. 84. Three tiered stage. Fig. 85-86. Upper tier in a state of division at the constricted region producing haustorial cells (HC) and endosperm cells (END). Z-Oospore. Fig. 87. Abnormal 3-nucleate 2-celled chalazal haustorium. Fig. 90-93. Various types of micropylar haustoria (8-celled in Fig. 93). Fig. 94. Mature 4-celled micropylar haustorium, the lowermost are endosperm cells. Topmost is cut end of synergid. Fig. 95. Mature chalazal haustorium (After Ganguly, 1948).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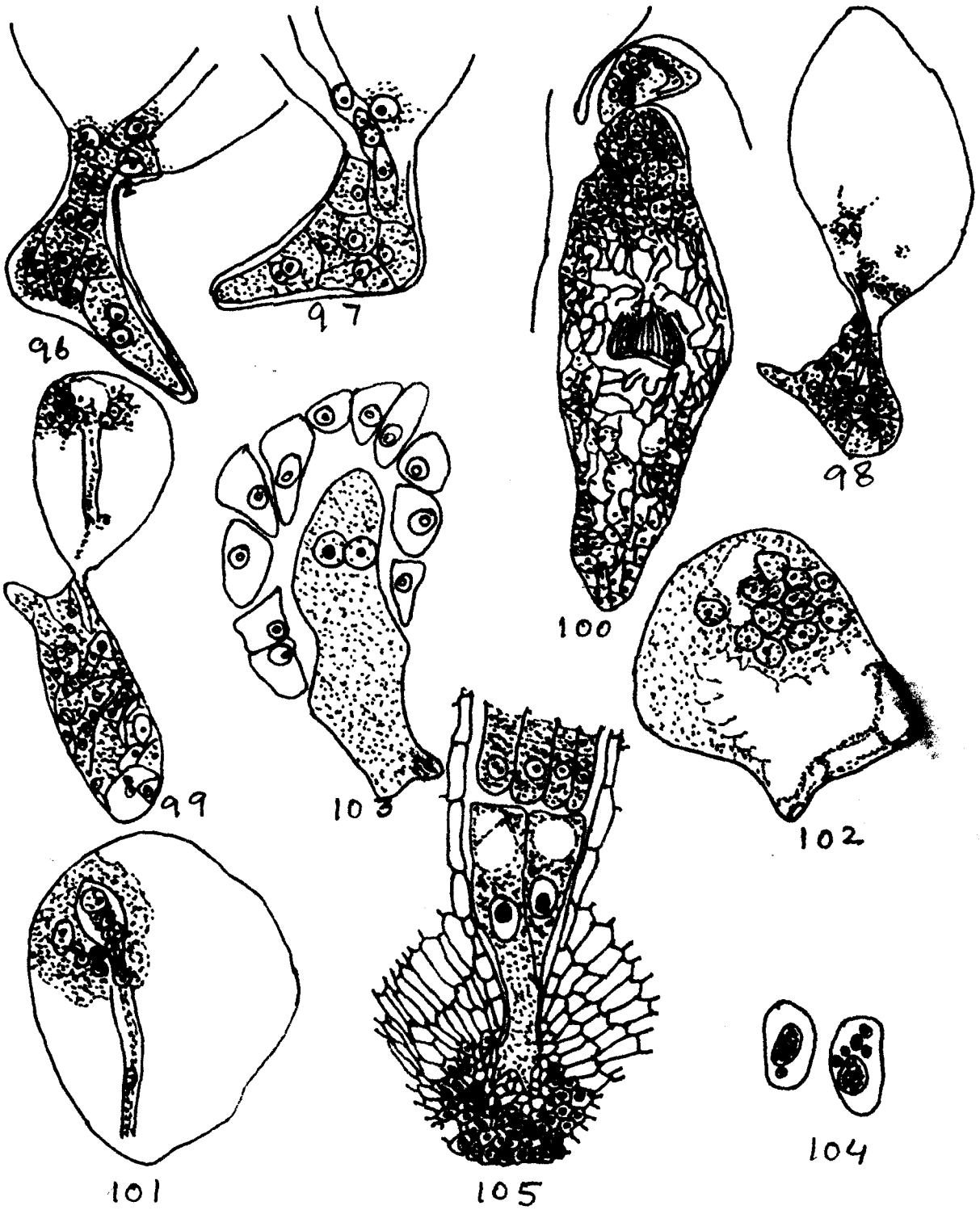
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EMBRYOGENY

The embryogeny conforms to the Onagrad type in the described Labiatae, viz., Physostegia virginiana (Sharp, 1911), Mentha viridis, Glechoma hederacea (Soueges, 1921), Mentha, Lycopus (Ruttle, 1931, 1932), Ocimum sanctum, O. canum, O. basilicum (Murthy, 1940), Globularia vulgaris (Crete, 1943), O. adscendens, Anisomeles indica, A. malabarica (Murthy, 1946), A. indica, Leonurus sibiricus (Ganguly, 1948), Brystropogon origanifolius (Crete, 1948), Scutellaria columnae (Jaitly, 1968), Mentha aquatica Jaitly, 1969), Salvia officinalis, S. sclarea (Polishchuk, 1972), O. basilicum (Kandelaki and Kobakhidze, 1977) and Leucas procumbens (Satyanarayana, 1985).

The zygote starts division when sufficient amount of endosperm is formed. The zygote undergoes extreme elongation and becomes embedded in the middle of actively dividing central endosperm cells as in most of the Labiatae, as reported in Anisomeles indica, A. malabarica, Ocimum adscendens (Murthy, 1946), Leonurus sibiricus and A. indica (Ganguly, 1948). The entrance of the zygote into the endosperm is very interesting in Leonurus (Ganguly, 1948) where it has been found to break through the wall of one of the two endosperm cells lying at the constricted region of the embryosac and passes into the endosperm tissue immediately

destroying the cell. The zygote starts division within 46 hours of the pollination becoming embedded in the endosperm proper in Ocimum basilicum (Kandelaki and Kobakhidze, 1977) and seven to eight days after pollination in Mentha piperata (Admiral'skaya 1960).

The first division of the zygote is transverse forming a two celled proembryo comprising a primary embryonal or apical cell, Ca, and a primary suspensor or basal cell, Cb. The apical cell, Ca, divides longitudinally and the basal cell, Cb, transversely producing a T-shaped pro-embryonic tetrad (Fig. 106). The two juxtaposed cells at the apex then divide almost simultaneously (Fig. 108) or one before the other (Fig. 107) by two longitudinal divisions giving rise to a quadrant pro-embryo (Fig. 109). The quadrant cells divide periclinally to form an octant pro-embryo comprising four long outer cells and four inner cells in Leonurus sibricus (Ganguly, 1948) and not transversely as in most of the Labiatae (Fig. 110).

The division of the cells m and ci of the four celled pro-embryo is initiated simultaneously with those of the apical cells in Leonurus (Ganguly, 1948). The cell m divides transversely forming the cells d and f (Fig. 107 and 108). Thd division of m is rather unequal, the upper cell d being smaller than the lower cell f. The apparently very small size of the cell d is perhaps due to a curving of

the pro-embryo at that region. Moreover, the partition between those two cells may also be obliquely oriented. Later the lower cell, ci divides transversely to form n and n' (Fig. 111). The upper cell n again divides forming n" and n"' (Fig. 110). These divisions also take place before the octant embryo is formed. The basal cell, cb, of the pro-embryo therefore gives rise to five cells, viz., d, f, n', n" and n"'. However, m and ci divide some what late in Brystropogon origanifolius (Crete, 1963).

The dermatogen is differentiated with the formation of the octant embryo, where all the cells are arranged in linear files instead of being formed into transverse layers. The series of divisions (mostly transverse) follow after the separation of the dermatogen layer. The inner octant cells divide transversly and tangentially producing a layer of periblem, pr, on each side below the dermatogen and two inner layers of plerome, pl. (Fig. 114). The apical row of cells of the dermatogen, 1 constitutes the cotyledon and stem apex, while the lower layer, 1' represents the hypocotylar region (Fig. 112-114). When the cotyledonar lobes have just differentiated there appear two layers each of periblem, pr and plerome, pl on each side of the hypocotylar axis (Fig. 119). The outermost layer of the plerome pl is the pericycle.

The cell d has divided into two apparently unequal

cells, either by a straight horizontal wall or by a curved wall thus clearly establishing its nature by inserting the wall of dermatogen cells of the hypocotyl. In one instance an oblique wall has been laid after the division of the cell d, one of the wall being inserted on the peripheral membrane of the pro-embryo has been reported in Mentha viridis (Souege, 1921) and Leonurus (Ganguly, 1948). The separating wall in (Ganguly, 1948) may even lie entirely on the proembryonal membrane where both the cells have again undergone vertical and oblique divisions respectively, the lower cell of d actually forming a part of the suspensor thus extending the differentiation of the hypophysis to a later stage. The upper cell of the products of d appears narrow, possibly because of the curving of the embryo at this region.

Both the cells derived from d usually divide vertically producing a tetrad hypophysis but the lower may exceptionally segment transversely adding to the suspensor filament (Fig. 112). As the cell divisions progress in the embryo, the suspensor cells also divide resulting in a row of six or seven cells in Ocimum adscendens (Murthy, 1946) and eight or more cells in Anisomeles indica and A. malabarica (Murthy, 1946). In A. indica and A. malabarica (Murthy, 1946) the suspensor cells persist until the embryo reaches the spherical stage after which degeneration starts from the micropylar region. Except for two cells immediately next to the embryo the suspensor degenerates after the

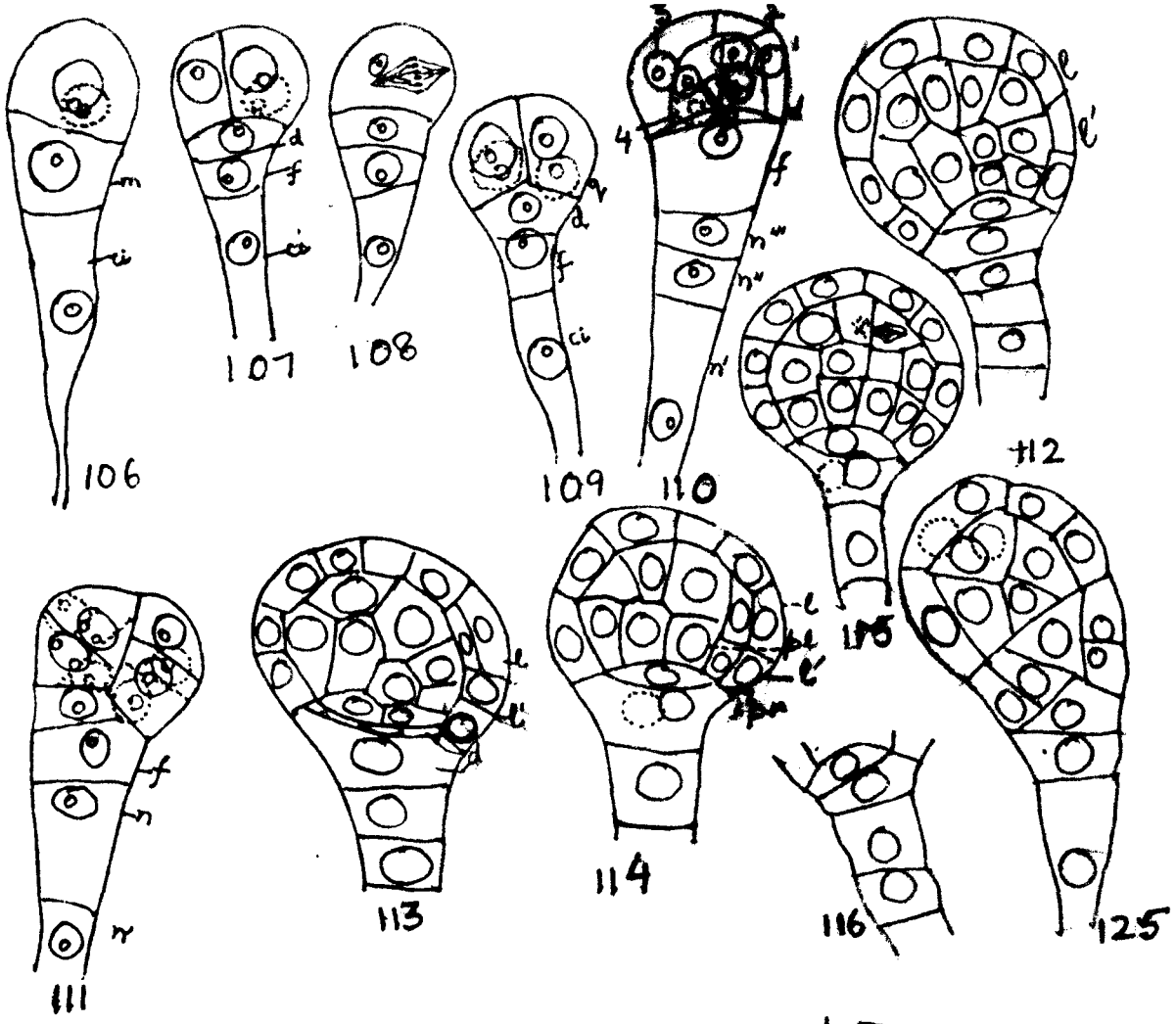
embryo develops cotyledonary buldges in O. adscendens (Murthy, 1946). The palisade layers differentiate as the cotyledons. The cells of the embryo are densely filled with the starch grains of variable size. The embryo finally displaces the endosperm in all the investigated Labiatae.

The two lower cells of the tetrad hypophysis (product of d) divide tangentially to produce four cells which give rise to the median portion of the root-cap, Rc, by further vertical divisions (Fig. 119 and 120). The two upper cells derived from d contribute to the root-apex, RA, by continuing vertical divisions (Figs. 119-121) or both by vertical and transverse divisions (Fig. 122). In the upper portion of the root on the two sides, the two root cap layers are joined by the tangential divisions of the dermatogen pertaining to the hypocotyl where it extends to a certain distance.

Several irregular configurations of cells of the hyphysial region have been reported in Leonurus (Ganguly, 1948) (Fig.123-125). Sometimes, at the fourth cell generation 12 cells are disposed in 6 tiers. Eight cells are derived from the apical cell, Ca, and four from the basal cell, Cb. This has been termed as Mentha-variation of Onagrad type. This type of embryogeny has been reported in Ajuga reptans, Teucrium botrys, Amethystea ceerula, Prasium majus, Scutellaria minor, Marrubium pannonicum,

Sideritis hirsuta, S. scordioides, Nepata cataria, N. macrantha, Dracocephalum ruyschiana, D. mairei, D. thymifolium, Lophanthus chinensis, Lallemantia peltata, L. iberica, Brunella vulgaris, Melittis melissophyllum, Pholmis alpina, Leonurus cardiaca, Salvia sclarea, Thymus serphyllum Origanum vulgare, Perilla arguta, Ocimum basilicum (Johansen, 1950), Salvia columnae (Jaitly, 1968), Mentha aquatica (Jaitly, 1969), S. coccinea and S. splendens (Jaitly, 1972).

On the other hand, Lamium-variation of Asterad type has also been observed in Labiatae. In this type of embryogeny the zygote divides by a transversely oblique wall. Both Ca and Cb contribute to the construction of the embryo proper. The apical cell, Ca, divides longitudinally and the basal cell, Cb, transversely producing a T-shaped pro-embryonic tetrad. The two cells derived from the basal cell are m and ci. The apical cell further divides by a wall oriented perpendicularly to the first longitudinal wall to form a quadrant. The quadrant cells divide further by means of the oblique walls. The middle cell becomes transformed into a quadrant by two longitudinal divisions. The cells along with the upper daughter originating from the transverse division of the basal cell, go into the formation of the hypocotyle. The suspensor consists of more than two cells, none being vesicular. Lamium-variation of the Astered type has been reported in Galeopsis tetrahit, G. pyrenaica, Lamium purpureum and Bellota foetida (Johnsen, 1950).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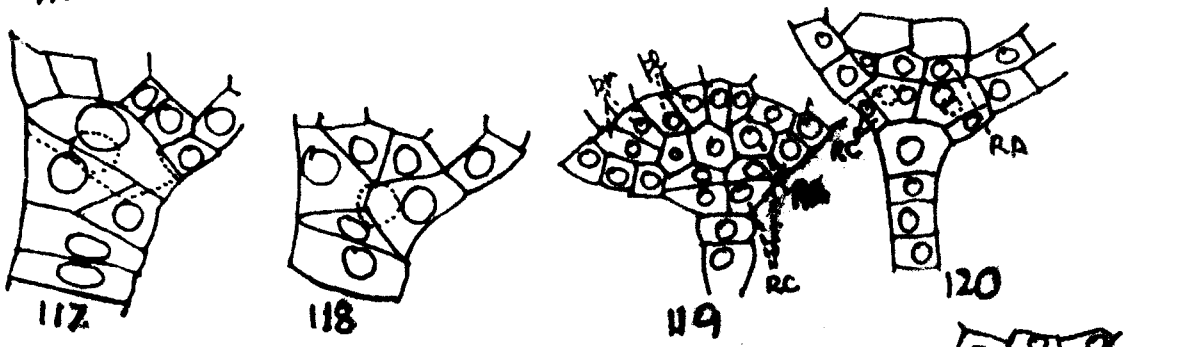
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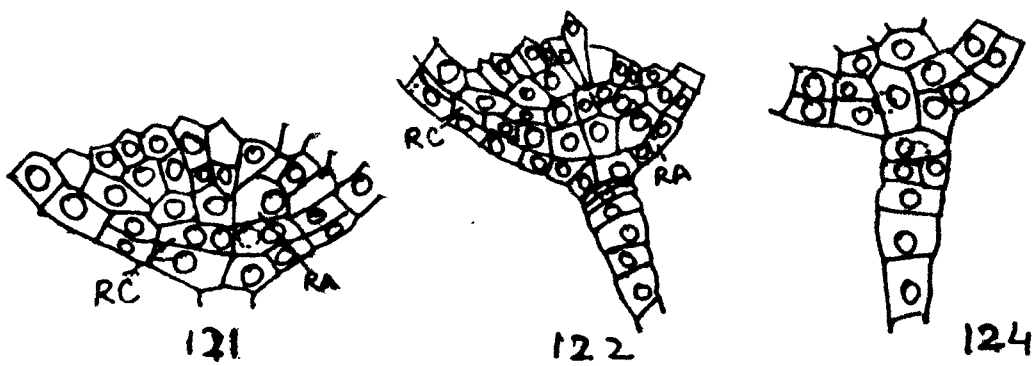
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FRUIT AND SEED

The fruit in Labiatae is usually a group of four achenes or nutlets which are equally developed, each containing a single seed as reported in Salvia, Orthosiphon, Acrocephalus and Lavandula (Mathur, 1956). However, the fruit is reported to be schizocarpic and carcerulus in Ocimum sanctum and drupaceous in Gomphostemma (Mathur, 1956). The nutlets in Anisomeles indica (Jaitly, 1966) are small, non-mucilagenous and shinning black with a smooth surface. They are slightly triangular in shape, convex dorsally and angular ventrally with obtuse anterior and posterior ends. In Salvia coccinea the nutlets are oblong lanceolate with a conical apex while those of S. splendens possess lateral and median ridges in the apical region (Jaitly, 1971). The length and breadth of the nutlets in A. incida (Jaitly, 1966) vary from 1.59 to 1.74 mm and 1.15 to 1.23 mm respectively. While in S. coccinea the length and breadth are 3.0 mm and 1.21 to 1.31 mm and in S. splendens it is 3.0 to 3.25 mm and 1.69 to 1.79 mm respectively (Jaitly, 1971). Another marked difference between the nutlets of the two species of Salvia is the presence of light-yellow patches dispersed at random against a brown background in S. coccinea (Jaitly, 1971). These are absent in S. splendens (Jaitly, 1971). The scar of the fruit stalk in

A. indica (Jaitly, 1966) is circular, situated on ventral surface at the tip of the anterior end, more or less oval in S. coccinea (Jaitly, 1971) and triangular in S. splendens (Jaitly, 1971). When the nutlet of A. malabarica and A. indica (Murthy, 1946) is immersed in water it becomes coated with mucilage after some time. While the nutlets are covered with a dirty horny substance which on being soaked in water swells up and becomes slimy in S. coccinea and S. splendens (Jaitly, 1971).

The wall of the ovary which forms the protective coat originally consists of five homogenous layers of cells in the early endosperm stages, which later differentiate into distinct regions (Figs. 127, 129 and 131). The inner and outer epidermal cells develop thick walls. The wall of the nutlet in Anisomeles indica and A. malabarica (Murthy, 1946) consists of outer mucilagenous layer and inner protective layer. In Ocimum adscendens (Murthy, 1946) the cells of the inner epidermal layer enlarge and develop striate thickenings (Fig. 128). In each cell the contents and the nucleus gradually disintegrate. The cell lumen is reduced by the development of thickenings on their walls so that the cells become stony in character. The middle and inner epidermal cells in Salvia splendens and S. coccinea (Jaitly, 1971) grow tangentially. The outer epidermal cells in O. adscendens (Murthy, 1946) enlarge, and the thickening takes place only

along the radial walls. The cell contents along with the nucleus are gradually shifted towards the centre of the cell where they are organised into a mass supported by a stalk-like appendage arising from the base of the cell. The cytoplasm is transformed into a bunch of mucilage globules. In Salvia splendens and S. coccinea (Jaitly, 1971) the outer walls of the outer epidermis develop cellulose thickening soon after fertilization. The outer wall of the outer epidermal cells in both the species of Salvia become thick at globular stage of the embryo and their nuclei show degeneration. The cells of the middle layers between the outer and inner epidermis of the ovary wall elongate radially and develop fibrous thickenings in Ocimum adscendens, Anisomeles indica, A. malabarica (Murthy, 1946), S. splendens and S. coccinea (Jaitly, 1971). The middle zone in S. coccinea has regular cells while in S. splendens it is irregular in shape, ruptured at places and contain scanty cytoplasm (Jaitly, 1971). Thickenings of the inner hypodermal cells start along the walls away from the epidermis. These thickenings later on change to lignin from cellulose. The cells of the middle layer later on elongate tangentially and become irregular in outline. A thick pericarp is found enclosing a massive embryo in A.indica and A. malabarica (Murthy, 1946) (Fig. 130). Compound starch grains which break up into four or more bits are found in all the pericarp cells of A. indica and A. malabarica (Murthy, 1946). The pericarp becomes 9-12 layered in S. coccinea

(Jaitly, 1971) and 24-26 layered in S. splendens (Jaitly, 1971). The cells of the endosperm are filled with starch grains in Anisomeles malabarica (Murthy, 1946) (Fig. 132).

In Labiatae, the seeds are albuminous or exalbuminous. The albuminous seeds have been reported in Leucas and Pogostemon (Jaitly, 1969), while in Hyptis, Mentha, Ocimum and Salvia (Jaitly, 1969) the seeds are exalbuminous. The albuminous seeds are those seeds in which endosperm is present, while the exalbuminous seeds are without endosperm. The seeds of Salvia hormium (Grubert, 1980) are mucilage producing. The embryos in the seeds may be straight, curved or coiled with flat or folded cotyledons.

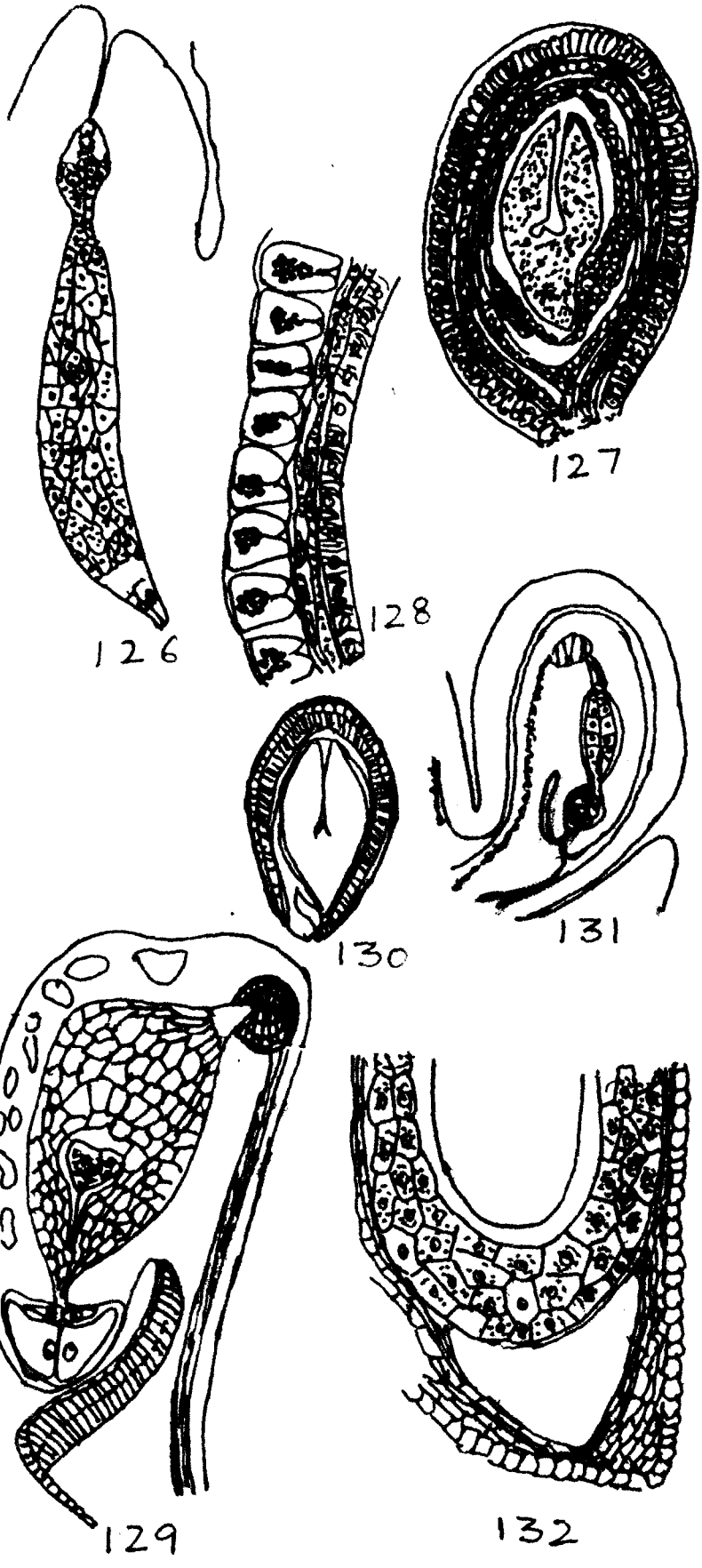
At the mature embryo sac stage the nucellus is totally absorbed and the integument consists of many layers. The integument is 5-layered in Ocimum adscendens (Murthy, 1946) and Anisomeles indica (Jaitly, 1966), 7-9-layered in Saliva (Jaitly, 1971), 9-10-layered in S. splendens (Jaitly, 1971) and 10-12-layered in S. coccinea (Jaitly, 1971). The inner most layer of the integument differentiates as endothelium during megagametogenesis in the investigated Labiatae except Salvia splendens and S. coccinea (Billings, 1909; Carlson and Stuart, 1936). However, in a single case in S. splendens Jaitly (1971) observed the endothelium. The endothelium degenerates during the seed formation.

The outer epidermis of the integument along constitutes

the seed coat in Leucas procumbens (Satyanarayana, 1985). The seed coat is 1-2 layered in Hyptis, Mentha, Ocimum (Mathur, 1956) and Anisomeles indica (Jaitly, 1966). The inner walls of cells of the two layered seed coat of A. Indica (Jaitly, 1966) develop spinulose thickenings with coalesce rendering the radial and tangential walls thick. The seed coat in Leucas, Leonurus, Molucella and Salvia (Jaitly, 1971) consists of 2-3 layeres of ruptured and degenerated cells. The seed coat in Salvia coccinea and S. splendens (Jaitly, 1971) appears as a dark brown strip. It is composed of 2-3-layers of crumpled and ruptured cells of epidermis and hypodermis of the integument. In Pogostemon and Anisomeles (jaitly, 1969) the seed coat is very thick.

Explanation of Figures

Fig. 126. *Anisomeles indica*; Advanced stage of seed (After Ganguly, 1948). Fig. 127-128. *Ocimum adscendens*; Fig. 127. L.S. of the nutlet some-time before shedding. Fig. 128. Development of striate thickenings on inner epidermis (After Murthy, 1946). Fig. 129-132. *Anisomeles malabarica*; Fig. 129. L.S. through a fairly old ovule showing prominent vascular trace, obturator endosperm regions and embryo. Fig. 130. L.S. through a ripe nutlet showing the pericarp and embryo. Fig. 131. L.S. through a young nutlet showing obturator, endosperm regions, hypostase and prominent vascular trace. Fig. 132. Micro-pylar region of the ovule at a late stage showing empty haustorial cavity and endosperm filled with starch grains (After Murthy, 1946).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SUMMARY AND CONCLUSION

A comparitive morphological and embryological study of the different species of Labiatae has been reviewed. The floral parts differentiate in acropetal succession in Salvia, Ocimum and Lavandula, while in Anisomeles and Leonurus the floral organogeny occurs alternately in acropetal and basipetal successions.

Microsporangium is tetra-sporangiate and the development of the anther wall conforms to the Dicotyledonous type of Davis (1966). The anther wall comprises an epidermis, endothecium, middle layers and a glandular tapetum. The endothecium is usually single-layered. The fibrous thickenings generally develop in the cells of endothecium except the cleistogamous flowers of Lamium amplexicaule (Gorzczyński, 1929). The fibrous endothecium is hygroscopic in nature and helps in dehiscence of the anther. The middle layers are generally 2-3 and degenerate during pollen maturity. The glandular tapetum is of dual origin and their cells become multinucleate (Davis, 1966). Male archesporium is uniseriate and the microsporogenesis is non-synchronous. Simultaneous cytokinesis in the microspore mother cells follows meiosis. The microspore tetrads are tetrahedral or decussate in Labiatae depending upon the direction of spindles (Davis, 1966).

Isobilateral tetrads are reported in Leucas procumbens (Satyanarayana, 1985). Several unusual features are associated with the process of microsporogenesis in Salvia mellifera and S. apiana (Carlson and Stuart, 1936). The nucleolar budding occurs in S. apiana during meiosis. Anaphase I may be accompained by non-disjunction of some bivalents in both the species of Salvia. True furrowing occurs in both the species. In S. mellifera the furrow extends centrifugally without accompanying central vacuolation. In S. apiana a central vacuole assists invagination.

Each microspore is having a monoploid (N) nucleus. The pollen grains are 2-3 celled at the shedding stage. The wall of the mature pollen grain is stratified. The exine of the pollen grains in Labiatae may be psilate, reticulate, thinner towards colpi margins, granulose, crustate, areolate or retipilate. The pollen grains may be prolate or sub-oblate. The size of the pollen grains varies from genus to genus and sometimes within species (Nair, 1965). On the basis of the apertures the pollen grains are classified into 3-zonicolpate and stephanocolpate (Rao and Shukla, 1975). The 3-zonicolpate pollen grains are shed at 2-nucleate stage while 6-colpate at 3-nucleate stage (Nair, 1965).

The ovule in Labiatae is hemianatropous to anatropous, unitegmic and tenuinucellar (Davis, 1966). The anatropous ovule has been reported in Physostegia (Sharp, 1911)Monarda fistulosa, M. didyma, M. punctata, Nepata cataria (Bushnell,

1936), Ocimum Sanctum, O. basilicum and O. canum (Murthy, 1940), Anisomeles indica, A. malabarica (Murthy, 1942, 1946), O. adscendens (Murthy, 1946), A. indica (Jaitly, 1966), Salvia splendens and S. coccinea (Jaitly, 1972). In Leonurus (Ganguly, 1948), the ovule curves along the funicle as well as its lower portion. The curvature is continued upto the tetrad stage. This brings about a some what campylotropous condition which is more apparent in mature stage of the gametopyte.

The ovule of Labiatae has a single massive integument. The ovule usually possesses a funcicular obturator. The nucellar epidermis remains single layered in Labiatae except Anisomeles indica and Leonurus sibiricus (Ganguly, 1948), where the two upper cells undergo a periclinal divison. The presence of an integumentary tapetum covering the embryo sac is a characteristic feature of Labiatae. The ex-extent to which endothelium encloses the embryo sac varies in different species (Davis, 1966).

The female archesporium is generally single-celled in Labiatae. However, 2-celled female archesporium has been reported by Strasburger (1889) and Schnarf (1917) in Galaeopsis pubescendens and Lamium respectively. The existence of 2-megaspore mother cells has also been detected either superimposed or lying side by side in Leonurus (Ganguly, 1948) and Pogostemon patchouli (Junell, 1937). In Leonurus sibiricus (Ganguly, 1948), in one instance, six archesporial cells have

been observed and among these the upper two are slightly larger. In Leonurus (Ganguly, 1948), 2-5 embryo sacs were observed lying side by side in one instance and only one of them reached 8-nucleate. From the double and multiple archesporium in Leonurus (Ganguly, 1948) the double megaspores are formed, the latter again resulting in the double tetrads, out of which only 2-chalazal megaspores developed into the characteristic double embryo sac. Potential archesporial cells have been reported in Molucella and Pogostemon (Junell, 1937).

In Labiatae, the archesporial cell directly functions as the megaspore mother cell (Davis 1966). The megaspore tetrad is generally linear. Three micropylar megaspores degenerate, while the chalazal one enlarges and gives rise to an eight nucleate embryo sac. (Davis, 1966). The mature embryo sac comprises an egg apparatus, two polar nuclei and three antipodals. The development of the female gametophyte in Labiatae conforms to the Polygonum type. Double and multiple embryo sacs have been observed in Leonurus (Ganguly, 1948) and Salvia officinalis (Polishchuk, 1972).

The synergids are hooked in Anisomeles, Leonurus, Mentha, Orthosiphon and Stachys and the polar nuclei fuse before or at the time of fertilization. The antipodals undergo secondary multiplication. They are ephemeral and degenerate after fertilization, except Physostegia (Sharp, 1911).

The occurrence of the starch grains at the chalazal region of the mature embryo sac has been observed in Lallemantia iiberica, Salvia tilifolia, Hormium Pyrenaicum, Ziziphore capitata, Elscholtzia cristata, Hyptis pectinata, Plectranthus ortendahlii, (Junell, 1937), Ocimum (Murthy, 1940, 1946), Orthosiphon stamineus (Murthy, 1947) Anisomeles malabarica and A. indica (Murthy, 1942, 1946).

The pollination in Labiatae is entomophilous and anemophilous. The fertilization is porogamous. Double fertilization is of common occurrence. The pollen grains germinate on the stigma and the pollen tubes grow through the gynobasic style and find their way into the ovules, where they discharge the sperms in the vicinity of the egg apparatus. One of the sperm fuses with the egg(forming zygote), while the other fuses with the polar nuclei or with the secondary nucleus forming the primary endosperm nucleus.

The development of endosperm starts immediately after fertilization, while the division in zygote is delayed considerably until sufficient amount of endosperm is formed. The development of endosperm in Labiatae conforms to Cellular type (Davis, 1966). The primary endosperm cell divides transverselly and, according to the planes of divisions in the two chambers, Schnarf (1917b) recognized 4 main endosperm types-Scutellaria, Brunella, Stachys and Galeopsis. More than one type of endosperm development occur in different species of some genera like Salvia, Leonurus and

Anisomeles (Kumari, 1976).

Formation of endosperm haustoria is of common occurrence in the family Labiatae. There are few members of Labiatae where both the chalazal and the micropylar houstoria have been reported to the Cellular viz., Westringia (Billings, 1909, Kumari, 1976), Leucas aspera (Murthy, 1941), Anisomeles Malabarica A. indica, Ocimum adscendens (Murthy, 1946), Orthosiphon stamineous (Murthy, 1947), Anisomeles, Leonurus (Ganguly, 1948), A. indica (Jaitly, 1966), Salvia coccinea, S. splendens (Jaitly, 1971), S. officinalis and S. sclarea (Polishchuk, 1972). The number of cells and nuclei in the haustoria differ from genera to genera and sometimes with in species.

The embryogeny in Labiatae conforms to the Onagrad type in the described Labiatae, viz., Scutellaria columnae (Jaitly, 1968), Mentha aquatica (Jaitly, 1969) Salvia officinalis, S. sclarea (Polishchuk, 1972), O. basilicum (Kandelaki and Kobabhidze, 1977) and Leucas procumbens (Styanarayana, 1985). The mode of development of the embryo in Salvia columnae (Jaitly, 1968), S. coccinea, S. splendens (Jaitly, 1969) conforms to the Capsella-bursa pastoris type (Mentha variation of Onagrad type). In Galeopsis tetrahit G. pyrenaica, Ballota foetida Lamium purpureum and Urtica pullulifera the embryogeny fonforms to Lamium variation of the Asterad type (Johnsen, 1950). The embryos in Labiatae are straight curved or coiled with flat or folded cotyledons.

The fruit in Labiatae is usually a group of four achenes or nutlets which are equally developed, each containing a single seed e.g. Salvia, Orthosiphon, Acrocephalus and Lavandula. In a few cases the pericarp becomes fleshy or is produced into a wing like membranous structure. In Gomphostemma the nutlets are drupaceous. In Ocimum sanctum the fruit is reported to be schizocarpic and carcerulus (Mathur, 1956).

The seeds of Labiatae may be albuminous or ex-albuminous. The albuminous seeds are reported in Leucas and Pogostemon (Jaitly, 1969), while in Hyptis, Mentha, Ocimum and Salvia (Jaitly, 1969) the seed are ex-albuminous. The seeds of Salvia hormium (Grubert Meinhard, 1980) are mucilage producing. The seed coat consists of 1-2 layers in Hyptis, Mentha and Ocimum and 2-3 degenerated or ruptured layers IN Leonurus, Leucas, Molucella and Salvia (Mahtur, 1956). In Pogostemon and Anisomeles (Jaitly, 1969) the seed coat is multi-layered. Considerable variation exists in the size and structure of the seeds in different genera of Labiatae.

CONCLUSION:

The flowers in Tubiflorae are bisexual, actinomorphic often zygomorphic, tetracyclic and hypogynous. In the primitive members of Tubiflorae the flowers are actinomorphic, tetracyclic and isostamenous; while in highly evolved ones they are zygomorphic with reduced number of stamens, carpels,

placenta and ovules. Labiatae, Verbenaceae and Orobanchaceae are considered to be advanced families where the number of stamens and ovules per carpel is reduced. In these families the flowers are zygomorphic, bilipped corolla and stamens usually four which are didynamous. Sometimes fifth stamen may be represented by a staminode.

There are remarkable similarities of the embryological features in the order Tubiflorae. The anther wall follows Dicotyledonous type (See Davis, 1966). The tapetum is glandular. The pollen grains are 2-3 nucleate at the shedding stage. Dehiscence of the anther is by longitudinal slits. The ovules are usually anatropous, unitegmic and tenuinucellate. Hypodermal female archesporium is generally single celled and directly functions as the megasphore mother cell. The development of female gametophyte conforms to the Polygonum type. The embryogeny in Tubiflorae usually conforms to the Onagrad type, but other principal types may also occur frequently.

Considerable differences also occur in the embryological features which could be helpful in identification of the species, genus as well as sequencing the families within the order Tubiflorae. The family Labiatae shares some common features with Verbenaceae and Orobanchaceae. The anther wall comprises epidermis, fibrous thickenings in endothecium, middle layers and glandular tapetum. Cytokinesis is simultianeous. The tetrads are tetrahedral or isobilateral or decussate in

all the three families Synergids are hooked or beaked. Polar nuclei fuse before or at the time of fertilization. The endosperm is cellular in all the three families. In Orobanchaceae, Brunella type of cellular endosperm is reported; while the cellular endosperm in Labiatae is of 4-main types Brunella, Stachys, Scutellaria and Galaeopsis depending upon the sequence of early divisions (Schnarf, 1917). The formation of both the endosperm haustoria is of common occurrence in all the three families. The embryogeny conforms to the Onargrad type. Rosen (1947) regards the cellular endosperm to be the most primitive type while Helobial and Nuclear are derieved from it. The four main types of cellular endosperm in Labiatae are of much phylogenetic significance.

The family Labiatae is distinguished from all other families except Verbenaceae by the presence of distinct gynobasic style. The seperation of the ripe fruit into four nutlets has led to an association with Boraginaceae. The family Boraginaceae differs from Labiatae by the character of ovule. In Boraginaceae the micropyle faces upwards while in labiatae the micropyle faces inwards.

Considering the morphological and embryological features of Labiatae, the family, is closely related to Verbenaceae and Orobanchacea.

On the basis of the cyto-embryological studies it can be concluded that differentiation of floral parts, origin and development of ovules and their fertility, development

of anther along with differentiation of all its layers and dehiscence patterns, origin and formation of tapetum, microsporogenesis, chromosome numbers and types of megaspore tetrads, origin and differentiation patterns of female gametophytes, trends of pollination, fertilization, endosperm and seed development are a characteristic features of a particular family, genus or a species and sometimes particular group of species. The comparitive embryological features are of taxonomic significance.

Considering the number of genera (200) and species (3000) in Labiatae and paucity of the embryological data, it is rather difficult to draw any definite conclusion. However extensive critical embryological study would yield fruitful result to trace the phylogeny within the family Labiatae as well as its relationship with the allied families.

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*Original not seen.

PLAN OF WORK

The flower buds and fruits of different developmental stages of Ocimum kilimandscharicum Guerke, O. gratissimum Linn., O. hirsutum Benth. and O. medium, Mill., would be collected from the garden of the Department. The materials would be fixed in F.A.A., dehydrated in alcohol xylol series, embedded in paraffin wax and sections would be cut at 8-12 um. The preparations would be stained with safranin and fast green combination.

The cyto-embryology of the above mentioned species would be investigated in considerable detail with a view to trace the sequence of evolution within the genus and its relationship with other genera of the family.